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CONTROL DATA 110

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PREFACE

PURPOSE

This manual describes the CYBIL programming language for the UCSD p-System™ (version IV.0).† The UCSD p-System operates on microcomputer systems such as the CONTROL DATA® 110.

AUDIENCE

This manual is written as a reference for CYBIL programmers. It assumes that you understand the manual for your computer system.

ORGANIZATION

This manual is organized by topic, based on elements of the CYBIL language. The first chapter introduces the basic concepts and elements of the language and refers you to the chapter in which each one is described.

CONVENTIONS

Within the formats for declarations, type specifications, and statements shown in this manual, uppercase letters represent reserved words; they must appear exactly as shown. Lowercase letters represent names and values that you supply.

Optional parameters are enclosed by braces, as in

```
{PACKED}
```

If the parameter is optional and can be repeated any number of times, it is also followed by several periods, as in

```
{name}...
```

For example, the notation {digit} means zero digits or one digit can appear; {digit}... means zero, one, or more digits can appear. Braces also indicate that the enclosed parameters are used together. For example,

```
{offset MOD base}
```

is considered a single parameter. Except for the braces and periods indicating repetition, all other symbols shown in a format must appear.

Numbers are assumed to be decimal unless otherwise noted.

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† UCSD p-System is a trademark of the Regents of the University of California.

RELATED MANUALS

You should be familiar with the material in the following publications.

Control Data Publication	Publication Number
CYBIL Handbook	60457290
Software Engineering Services User´s Handbook	60457250
Control Data 110 Owner´s Manual	62940053

DISCLAIMER

This product is intended for use only as described in this document. Control Data cannot be responsible for the proper functioning of undescribed features or parameters.

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INTRODUCTION 1

ELEMENTS IN A CYBIL PROGRAM

A CYBIL program consists essentially of two kinds of elements: declarations and statements. Declarations describe the data to be used in the program. Statements describe the actions to be performed on the data.

Declarations and statements are made up of predefined reserved words and user-defined names and values. The way you form these elements is described in chapter 2, as is the general structure for forming a CYBIL program.

DATA DECLARATIONS

Data can be either constant or variable. You can use the constant value itself or give it a name using the constant declaration (CONST). Variables are named and given certain characteristics with the variable declaration (VAR). One of the characteristics of a variable is its type, for example, integer or character. You can use CYBIL's predefined types or define your own types. To define a new type or redefine an existing type with a new name, you use the type declaration (TYPE).

TYPES

Once you have defined a type, CYBIL will treat it as a standard data type; you can specify your new type name as a valid type in a variable declaration and CYBIL will perform standard type checking on it. You can also declare where you want certain variables to reside by defining an area called a section, which can be a read-only section or a read/write section. This is done with the SECTION declaration. All of these data-related declarations are described in chapter 3.

Many standard types are available, including integers, floating-point numbers, characters, and boolean values, to name a few. In addition, you can use combinations of the standard types to define your own data types, for example, a record that contains several fields. The next few paragraphs summarize the types that are predefined by CYBIL. They are described in detail in chapter 4.

Among the basic types are scalar types, that is, those that have a specific order. Besides integer, character, and boolean values, you can declare an ordinal type in which you define the elements and their order. You can also specify a subrange of any of the scalar types by giving a lower and upper bound. Floating-point (real) numbers are also available. A pointer is a type that points to a variable, allowing you to access the variable by location rather than by name. A cell, which represents the smallest addressable unit of memory, can also be specified as a type. These are the basic types: scalar, floating point, pointer, and cell. With these basic types you can construct the structured types: strings, arrays, records, and sets.

A string is a sequence of characters. You can reference a portion of a string (called a substring) or a single character within a string. An array is a structure that contains components all of the same type. The components of an array have a specific order and each one can be referenced individually. A record is a structure that contains a fixed number of fields that may be of different types. Each field has a unique name within the record and can be referenced individually. You can also declare a variant record that has several possible variations (variants). The current value of a field common to all variants or the latest assignment to a specific variant field determines which of the variants should be used for each execution. A set is a structure that contains elements of a single type. Yet unlike an array, elements in a set have no order and individual elements cannot be referenced. A set can be operated on only as a whole.

Storage types are structures to which variables can be added, referenced, and deleted under explicit program control using a set of storage management statements. The two storage types are sequences and heaps.

All of the types mentioned above are considered fixed types; there is a definite size associated with each one when it is declared. If you want to delay specifying a size until execution time, you can declare it as an adaptable type. Then, sometime during execution, you assign a fixed size or value to the type. A string, array, record, sequence, or heap can be adaptable. All of these types are described in chapter 4.

STATEMENTS

Statements define the actions to be performed on the data you've defined. The assignment statement changes the value of a variable. Structured statements contain and control the execution of a list of statements. The BEGIN statement unconditionally executes a statement list. The WHILE, FOR, and REPEAT statements control repetitive executions of a statement list.

Control statements control the flow of execution. The IF and CASE statements execute one of a set of statement lists based on the evaluation of a given expression or the value of a specific variable. CYCLE, EXIT, and RETURN stop execution of a statement list and transfer control to another place in the program.

Storage management statements allocate, access, and release variables in sequences (using the RESET and NEXT statements), heaps (using the RESET, ALLOCATE, and FREE statements), and the run-time stack (using the PUSH statement).

All of the preceding statements are described in detail in chapter 5, along with the operands and operators that can be used in expressions within statements and declarations.

Statements can appear within a program (as described in chapter 2), a function, or a procedure.

FUNCTIONS

A function is a list of statements, optionally preceded by a list of declarations. It is known by a unique name and can be called by that name from elsewhere in the program. A function performs some calculation and returns a value that takes the place of the function reference. There are many standard functions defined in CYBIL and you can also create your own. Standard functions and rules for forming your own functions are described in chapter 6.

PROCEDURES

A procedure, like a function, is a list of statements, optionally preceded by a list of declarations. It also is known by a unique name and can be called by that name from elsewhere in the program. A procedure performs specific operations and may or may not return values to existing variables. You can use the standard procedures and also define your own. Chapter 7 describes the standard procedures and rules for forming your own procedures.

COMPILATION COMMAND

Chapter 8 describes the command you use to call the CYBIL compiler, tell it which files to use for input and output, and specify what kind of listing you want. It also describes directives that are available at compilation time to specify listing options, run time options, the layout of the source text and resulting object listing, and what specific portions of the source text to compile.

SUMMARY

In summary, chapters 2 through 7 describe the elements within a CYBIL program. Chapter 8 describes the command and directives that control how the program is actually compiled.

PROGRAM STRUCTURE 2

INTRODUCTION

This chapter describes how to form the individual elements used within a program and how to structure the program itself.

ELEMENTS WITHIN A PROGRAM

This section describes the characters that can be used within a program, the words and symbols for which CYBIL has specific meanings, and the words and values for which you define meanings. In addition, general rules on syntax (use of blanks, comments, punctuation, and spacing) are given.

VALID CHARACTERS

The characters that can be used within a program are those in the ASCII character set that have graphic representations (that is, can be printed). This character set is shown in appendix B. It contains uppercase and lowercase letters. In names that you define, you can use uppercase and lowercase interchangeably. For example, the name LOOP_COUNT is equivalent to the name loop_count.

CYBIL-DEFINED ELEMENTS

CYBIL has predefined meanings for many words and symbols. You cannot redefine or use these words and symbols for other purposes.

A complete list of CYBIL reserved words is given in appendix C. In the formats for declarations, type specifications, and statements shown in this manual, reserved words are shown in uppercase letters.

The following list shows the reserved symbols and gives a brief description of the purpose of each. They are discussed in more detail throughout this manual.

Symbol	Purpose
+, -, *, /, =, <, <=, >, >=, <>, :=, (,)	These symbols are primarily operators used in expressions. They are discussed in chapter 5.
;	The semicolon separates individual declarations and statements.
:	The colon is used in declarations as described in chapter 3.
,	The comma separates repeated parameters or other elements.

Symbol	Purpose
.	A single period indicates a reference to a field within a record as described in chapter 4.
..	Two consecutive periods indicate a subrange as described in chapter 4.
^	The circumflex indicates a pointer reference as described in chapter 4.
' '	Apostrophes delimit strings.
[ ]	Brackets enclose array subscripts, indefinite value constructors, and set value constructors as described in chapter 4.
{ }	Braces delimit comments. (Within the formats shown in this manual, they are also used to enclose optional parameters.)
? or ??	A single question mark or a pair of consecutive question marks indicate compile time statements and directives as described in chapter 8.

USER-DEFINED ELEMENTS

The following paragraphs describe how you form the names of elements, various kinds of constants (integer, character, boolean, ordinal, floating-point, pointer, and string), and constant expressions.

Names

You define the names for elements, such as constants, variables, types, procedures, and so on, that you use within a program. A name:

- Can be from 1 to 31 characters in length.
- Can consist of letters, digits, and the special characters # (number sign), @ (commercial at sign), _ (underline), and $ (dollar sign).
- Must begin with a letter. (There is an exception to this rule for system-defined functions and procedures that begin with the # or $ character.)
- Cannot contain blanks.

In the formats shown in this manual, names that you supply are shown in lowercase letters. Within a program, however, there is no distinction between uppercase and lowercase letters. The name my_file is identical to the name MY_FILE.

There is considerable flexibility in forming names, so you should make them as descriptive as possible to promote readability and maintainability of the program. For example, LAST_FILE_ACCESSED is more obvious than LASTFIL.

Examples:

Valid Names	Invalid Names
SUM	ARRAY
REGISTER#3	FILES&POSITIONS
POINTER_TABLE	2ND

The valid names are self-explanatory. Among the invalid names, ARRAY cannot be used because it is a reserved word; FILES&POSITIONS contains an invalid character (the ampersand); and 2ND does not begin with a letter.

Constants

A constant is a fixed value. It is known at compilation time and does not change throughout the execution of a program. It can be an integer, character, boolean, ordinal, floating-point number, pointer, or string.

Integer constants can be binary, octal, decimal, or hexadecimal. The base is specified by enclosing the radix in parentheses following the integer, as follows:

```
integer (radix)
```

Examples are 1011(2) and 19A(16). If the radix is omitted, the integer is assumed to be decimal. Integer constants must start with a digit; therefore, zero must precede any hexadecimal constant that would otherwise begin with a letter, for example, 0FF(16). Negative integer constants must be preceded by a minus sign. Positive integer constants can be preceded by a plus sign but need not be. Integer constants are restricted to 48 bits.

A character constant can be any single character in the ASCII character set. The character is enclosed in apostrophes in the following form:

```
'character'
```

Examples are 'A' and '?'. The apostrophe character itself is specified by a pair of apostrophes.

A boolean constant can be either FALSE or TRUE, each having its usual meaning.

An ordinal constant is an element of an ordinal type that you have defined. For further information, refer to Ordinal under Scalar Types in chapter 4.

Floating-point (real) constants can be written in either decimal notation or scientific notation. A real number written in decimal notation contains a decimal point and at least one digit on each side, for example, 5.123 or -72.18. If the number is positive, the sign is optional; if negative, the sign is required.

A real number written in scientific notation is represented by a number (the coefficient), which is multiplied by a power of 10 (the exponent) in the form:

```
coefficientEexponent
```

The prefix E is read as "times 10 to the power of"; for example,

    5.1E6

is 5.1 times 10 to the power of 6, or 5,100,000. The decimal point in the coefficient is optional. A decimal point cannot appear in the exponent; it must be a whole number. If the coefficient or exponent is positive, the sign is optional; if negative, the sign is required.

The pointer constant is NIL. It indicates an unassigned pointer. NIL can be assigned to a pointer of any type.

String constants consist of one or more characters enclosed in apostrophes in the following form:

    ´string´

An example is ´USER1234´, a string of eight characters. An apostrophe in a string constant is specified by a pair of apostrophes, for example, ´DON´´T´. A string constant can be empty, that is, a null string. You cannot reference parts (substrings) of string constants.

Constant Expressions

Expressions are combinations of operands and operators that are evaluated to find scalar or string type values. In a constant expression, the operands must be constants, names of constants (that you declare using the CONST declaration described in chapter 3), or other constant expressions within parentheses. Computation is done at compile time and the resulting value used in the same way a constant is used.

The general rules for forming and evaluating expressions are described under Expressions in chapter 5. These rules apply to constant expressions with the following exceptions:

- Constant expressions must be simple expressions (terms involving relational operators must be delimited with parentheses).
- The only functions allowed as factors in constant expressions are the $INTEGER, $CHAR, SUCC, and PRED functions with constant expressions as arguments.
- Substring references are not allowed.

SYNTAX

The exact syntax of the language is shown in the formats of individual declarations and statements described in the remainder of this manual. The following paragraphs discuss general syntax rules.

Blanks

Blanks can be used freely in programs except for the following rules:

- Names and reserved words cannot contain embedded blanks. Normally, constants cannot contain blanks either, but a character constant or string constant may.

- A name, reserved word, or constant cannot be split over two lines; it must appear completely on one line.

- Names, reserved words, and constants must be separated from each other by at least one blank, or one of the other delimiters such as a parenthesis or comma.

For further information, refer to Spacing later in this chapter.

Comments

Comments can be used in a program anywhere that blanks can (except in string constants). They are printed in the source listing but otherwise are ignored by the compiler.

A comment is enclosed in left and right braces: { }. It can contain any character except the right brace (}). To extend a comment over several lines, repeat the left brace ({) at the beginning of each line. If the right brace is omitted at the end of the comment, the compiler ends it automatically at the end of the line.

Example:

```
{this comment
{appears on
{several lines.}
```

Within this manual, the formats for declarations, type specifications, and statements use braces to indicate an optional parameter.

Punctuation

A semicolon separates individual declarations and statements. It must be included at the end of almost every declaration and statement. The single exception is MODEND which can, but need not, end with a semicolon if it is the last occurrence of MODEND in a compilation. Punctuation for specific declarations and statements is shown in the formats in the following chapters.

Two consecutive semicolons indicate an empty statement, which the compiler ignores. Spacing between the semicolons in this case is unimportant.

Spacing

Declarations and statements can start in any column. In this manual, indentations are used in examples to improve readability. It is recommended that similar conventions be used in your programs to aid in debugging and documentation for yourself and other users.

The LEFT and RIGHT directives, described in chapter 8, can be used at compilation time to specify the left and right margins of the source text. All source text outside of those margins is then ignored.

A name, reserved word, or constant cannot be split over two lines; it must appear completely on one line.

STRUCTURE OF A PROGRAM

This section describes the basic structure of a CYBIL program, that is, the module. It includes a discussion of the scope of elements within a program, how to declare a module, and how to declare a program.

MODULE STRUCTURE

The basic unit that can be compiled is a module and, optionally, compile time statements and directives. A module can, but need not, contain a program. The general structure of a module is:

```
MODULE module_name;
  declarations
  PROGRAM program_name;
    declarations
    statements
  PROCEND program_name;
MODEND module_name;
```

Declarations can be constant, type, variable, section, function, and procedure declarations. A module can contain any number and combination of declarations, but it can contain at most one program. The program contains the code (that is, the statements) that are actually executed. The required MODULE and PROGRAM declarations are described later in this chapter.

The structure within a module determines the scope of the elements you declare within it.

SCOPE

The scope of an element you declare, such as a variable, function, or procedure, is the area of code where you can refer to the element and it will be recognized. Scope is determined by the way the program and procedures are positioned in a module and where the elements are declared.

In terms of scope, programs, procedures, and functions are often referred to as blocks (that is, blocks of code). Generally, if an element is declared within a block, its scope is just that block. Outside the block, the element is unknown and references to it are not valid. A variable declared within a block is said to be local to the block and is called a local variable.

An element declared at the module level (that is, one that is not declared within a program, procedure, or function) has a scope of the entire module. It can be referred to anywhere within the module. A variable declared at the module level is said to be global and is called a global variable.

A block can contain one or more subordinate blocks. A variable declared in an outer block can always be referenced in a subordinate block. However, if a subordinate block declares an element of the same name, the new declaration applies while inside that block. Figure 2-1 illustrates these rules.

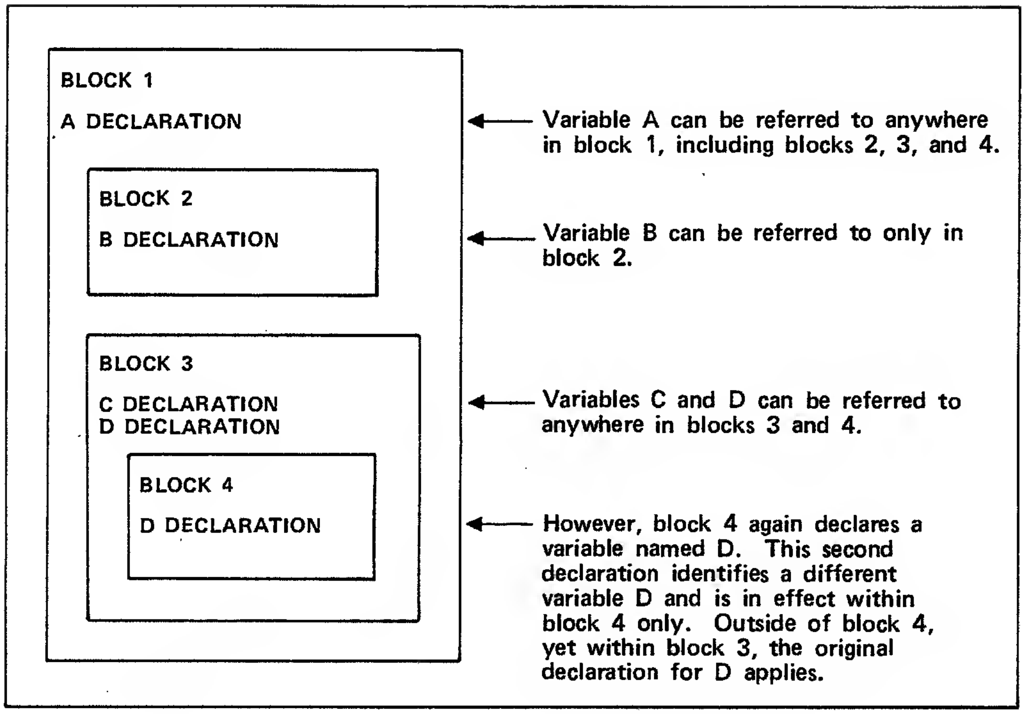


Figure 2-1. Scope of Variables Within a Block Structure

Storage space is allocated for a variable when the block in which it is declared is entered. Space is released when an exit is made from the block. Because space is allocated and released automatically, these variables are called automatic variables. You can specify that storage for a variable remains throughout execution by including the STATIC attribute when you declare the variable. A variable declared in this way is called a static variable. A global variable is always static. Because it is declared at the outermost level of a module (consider the module to be a block), storage for a global variable is allocated throughout execution of the module (block). For further information on automatic and static variables, refer to Variable Declaration in chapter 3.

The one exception to the preceding rules is an element declared with the XDCL (externally declared) attribute. This attribute means the element is declared in one module but can be referred to in another. In this case, the loader handles the links between modules. For further information on the XDCL attribute, refer to chapter 3.

MODULE DECLARATION

The MODULE declaration marks the beginning of a module. MODEND marks the end of a module. A module can contain at most one program and any combination of type, constant, variable, section, function, and procedure declarations. If two or more modules are compiled and linked together for execution, there can be only one program declaration in all the linked modules.

The format of the MODULE declaration is:

MODULE name {ALIAS 'alias_name'};†

name	The name of the module.
alias_name	An alternate name for the module which can be used outside of the compilation unit in which it is defined. The name must be enclosed in apostrophes. The keyword ALIAS and the alias_name are optional.

The format of MODEND is:

MODEND {name};

name	The name of the module. This parameter is optional. If used, the name must be the same as that specified in the MODULE declaration.

When compiling more than one module, a semicolon is required after each occurrence of MODEND except the last one. There it is not required but is recommended.

Examples:

The following example shows a module named ONE that contains various declarations and a program named MAIN. The module name and semicolon could be omitted following MODEND but it is recommended that they both be included.

```
MODULE one;
  declarations
  PROGRAM main;
    declarations
    statements
  PROCEND main;
MODEND one;
```

The following example shows a compilation consisting of three modules named ONE, TWO, and THREE. All three modules can be compiled and the resulting object modules linked together to form a single object module that can then be executed. For readability, the module names are included in all occurrences of MODEND. The semicolon could be left off the last occurrence of MODEND, but it is a good practice to include it.

```
MODULE one;
  declarations/statements
MODEND one;
MODULE two;
  declarations/statements
MODEND two;
MODULE three;
  declarations/statements
MODEND three;
```

†CYBIL P-Code accepts an alias name, but it is ignored.

PROGRAM DECLARATION

The PROGRAM declaration marks the beginning of a program. The end of a program is marked by a PROCEND statement. A program can contain any combination of type, constant, variable, section, function, procedure declarations, and any statements. If two or more modules are compiled and linked together for execution, there can be only one program declaration in the linked modules.

The format of the PROGRAM declaration is:

```
PROGRAM name {ALIAS 'alias_name'} {(formal_parameters)};†
```

name — The name of the program.

alias_name — An alternate name for the program which can be used outside of the compilation unit in which it is defined. The name must be enclosed in apostrophes. The keyword ALIAS and the alias_name are optional.

formal_parameters — One or more optional parameters included if the program is to be called by the operating system. They can be in the form

```
VAR name {,name}... : type
    {,name {,name}... : type}...
```

and/or

```
name {,name}... : type
     {,name {,name}... : type}...
```

where name is the name of the parameter and type is the type of the parameter, that is, a predefined type (described in chapter 4) or a user-defined type (described in chapter 3).

The first form is called a reference parameter; its value can be changed during execution of the program. The second form is called a value parameter; its value cannot be changed by the program. Both kinds of parameters can appear in the formal parameter list; if so, they are separated by semicolons (for example, I:INTEGER; VAR A:CHAR). Reference and value parameters are discussed in more detail later in this chapter.

The format of PROCEND is:

```
PROCEND {name};
```

name — The name of the program. This parameter is optional. If used, the name must be the same as that specified in the PROGRAM declaration.

†CYBIL P-Code accepts an alias name, but it is ignored.

The optional parameter list is included if a CYBIL program is to be called by the operating system. It allows the system to pass values (for example, a string that represents a command) to a CYBIL program. When the system calls a program, it includes parameters called actual parameters in the call. The values of those actual parameters replace the formal parameters in the parameter list one-for-one based on position; that is, the first actual parameter replaces the first formal parameter, and so on. Wherever the formal parameters appear in statements within the program, the values of the corresponding actual parameters are substituted. For every formal parameter in the program declaration, there must be a corresponding actual parameter.

When a reference parameter is used, the formal parameter represents the corresponding actual parameter throughout execution of the program. Thus, an assignment to a formal parameter changes the variable that was passed as the corresponding actual parameter. An actual parameter that corresponds to a formal reference parameter must be addressable. A formal reference parameter can be of any type.

When a value parameter is used, the formal parameter takes on the value of the corresponding actual parameter. However, the program cannot change a value parameter by assigning a value to it or specifying it as an actual reference parameter to a procedure or function. A formal value parameter can be of any type except a heap, or an array or record that contains a heap.

Example:

The following example shows a program named MAIN that contains various declarations, including a procedure named SUB_1.

```
PROGRAM main;
  declarations
  PROCEDURE sub_1;
    declarations
    statements
  PROCEND sub_1;
    statements
PROCEND main;
```

CONSTANT, VARIABLE, TYPE, AND SECTION DECLARATIONS 3

This chapter describes the constant declaration, which defines a name for a value that never changes; the variable declaration, which defines a name for a value that can change; and the type declaration, which defines a new type of data and gives a name to that type. In addition, it also includes the section declaration, which groups variables that share common access characteristics.

CONSTANT DECLARATION

A constant, as described in chapter 2, is a fixed value that is known at compile time and doesn't change during execution. A constant declaration allows you to associate a name with a value and use that name instead of the actual constant value. This provides greater readability because the name can be descriptive of the constant, and greater maintainability because the constant value need only be changed in one place, the constant declaration, not every place it is used in the code.

The format of the constant declaration is:

```
CONST name = value {,name = value}...;
```

name	The name associated with the constant value.
value	The constant value. It can be an integer, character, boolean, ordinal, floating-point, pointer, string, or constant expression. Rules for forming these values are described under Constants and under Constant Expressions in chapter 2.

You can write several constant declarations, each declaring a single constant, or a single declaration declaring several constants where each "name = value" combination is separated by a comma.

Type is not specified in a constant declaration. The type of the constant is the same as the type of the value assigned to it.

If used, an expression is evaluated during compilation. The expression itself can contain other constants.

Examples:

Rather than repeat the value of pi throughout a program, you can use a constant declaration to assign a descriptive name (in this case, PI) to the value and use that name in subsequent expressions and operations. The constant declaration is:

```
CONST pi = 3.1415927;
```

The following example shows a constant declaration containing several different types.

```
CONST
  first = 1,
  last = 80,
  hex = 0a8(16),
  bit_pattern = 10110101(2),
  stop_character = '.',
  continue = TRUE,
  message = 'end of line',
  last_pointer = NIL,
  length = last - first;
```

Each constant has the same type as the value assigned to it. For example, FIRST and LAST are integer types, as is LENGTH, which is the result of an expression containing integers. Notice that the value of HEX begins with a 0 (zero) because integers must begin with a digit.

VARIABLE DECLARATION

A variable is an element within a program whose value can change during execution. The name of the variable stays the same; it is only the value contained in the variable that changes. To use a variable, you must declare it.

The format for a variable declaration is:

```
VAR name {ALIAS 'alias_name'} {,name{ALIAS 'alias_name'}}... :
        {[attributes]} type

      {,name {ALIAS 'alias_name'} {,name{ALIAS 'alias_name'}}...:
            {[attributes]} type }...;†
```

name — The name of the variable. Specifying more than one name indicates that all of the named variables will have the characteristics that follow (attributes, type, and initial_value).

alias_name — An alternate name for the variable which can be used outside of the compilation unit in which it is defined. The name must be enclosed in apostrophes. When the alias_name is included in the variable declaration, the XDCL attribute must also be specified. The keyword ALIAS and the alias_name are optional.

attributes†† — One or more of the following attributes. If more than one are specified, they are separated by commas.

Attribute	Meaning
READ	Access attribute specifying that the variable is a read-only variable; the compiler checks to ensure that the value of the variable is not changed. If READ is specified, an initial value is required.

†CYBIL P-Code accepts an alias name, but it is ignored.

††Some variations of CYBIL available on other operating systems allow an additional attribute, the #GATE attribute. CYBIL P-Code accepts the #GATE attribute, but it is ignored.

Attribute	Meaning
XDCL	Scope attribute specifying that the variable is declared in this module but can be referenced from another module.
XREF	Scope attribute specifying that the variable is declared in another module but can be referenced from this module.
STATIC	Storage attribute specifying that storage space for the variable is allocated at load time and remains when control exits from the block. Static storage is assumed when any attributes are specified.
section_name	Storage attribute specifying the name of the section in which the variable resides. The section name and its read/write attributes must be declared using the SECTION declaration (discussed later in this chapter).

Attributes are described in more detail later in this chapter.

This parameter is optional. If omitted, CYBIL assumes the variable can be read and written; can be referenced only within the block where it is created; and, unless it is declared at the outermost level of a module, is automatic.

type — The data type defining the values that the variable can have. Only values within this data type are allowed. Types are described in chapter 4.

This parameter is optional. If omitted, the variable is undefined.

Any variable referenced in a program must be declared with the VAR declaration. A variable can be declared only once at each block level although it can be redefined in another block or in a contained (nested) block.

The type assigned to a variable defines the range of values it can take on and also the operations, functions, and procedures that can use it. CYBIL checks to ensure that the operations performed on variables are compatible with their types.

Examples:

The following declarations define a variable named SCORES that can be any integer number, a variable named STATUS that can be either of the boolean values FALSE or TRUE, and two variables named ALPHA1 and ALPHA2 that can be characters.

```
VAR scores : integer;
VAR status : boolean;
VAR alpha1 : char;
VAR alpha2 : char;
```

The declarations for the two character type variables, ALPHA1 and ALPHA2, could be combined as follows:

```
VAR alpha1, alpha2 : char;
```

To combine all of the variables in one declaration, you could use the following:

```
VAR scores : integer,
    status : boolean,
    alpha1, alpha2 : char;
```

ATTRIBUTES

Attributes control three characteristics of a variable:

- Access - whether the variable can be both read and written
- Scope - where within the program the variable can be referenced
- Storage - when and where the variable is stored

Access

The access attribute that you can specify is READ. A variable declared with the READ attribute can only be read. It is called a read-only variable. If the READ attribute is omitted, CYBIL assumes the variable can be both read and written (changed).

The READ attribute is enforced by software; that is, the compiler checks to ensure that the value of a variable does not change. The READ attribute alone does not mean that the variable is actually in a read-only section.† To do that, you must specify the name of a read-only section as declared in a SECTION declaration (described later in this chapter).

A variable with the READ attribute specified is assumed to be static. (For further information on static variables, refer to Storage later in this chapter.) A read-only variable can be used as an actual parameter in a procedure call only if the corresponding formal parameter is a value parameter; that is, a read-only variable can be passed to a procedure only if the procedure makes no attempt to assign a value to it. (Procedure parameters are described in chapter 7.)

A read-only variable is similar to a constant, but they can't always be used in the same places. As mentioned in chapter 2, you cannot reference a substring of a constant. You can, however, reference a substring of a variable and, thus, a read-only variable. There are other differences similar to these. The descriptions in this manual state explicitly whether constants and/or variables can be used.

Examples:

In this example, the variable DEBUG is a read-only variable set to the constant value of TRUE. NUMBER can be read and written.

```
VAR
  debug : [READ] boolean,
  number : integer;
```

---

†A read-only section is a hardware feature on some computer systems. Data that resides in a physical area of the machine designated as a read-only section is protected by hardware as opposed to software.

The following example illustrates a difference between constants and read-only variables. To declare a string type, you must specify the length of the string in parentheses following its name. As defined in chapter 4, the length must be a positive integer constant expression.

```
CONST
  string_size_1 = 5;

VAR
  string_size_2 : [READ] integer,
  string1 : string (string_size_1),
  string2 : string (string_size_2);
```

The declaration of STRING1 is valid; the length of the string is 5, the value of the constant STRING_SIZE_1. However, STRING2 is invalid; even though STRING_SIZE_2 does not change in value, it is still a variable and cannot be used in place of a constant expression.

Scope

The scope attributes define the part or parts of a module to which a variable declaration applies. If no scope attributes are included in the declaration, the scope of a variable is the block in which it is declared. A variable declared in an outermost block applies to that block and all the blocks it contains. However, a variable declared even at the outermost level of a module cannot be used outside of that module. The scope attributes, XDCL and XREF, are used to extend the scope of a variable so that it can be shared among modules.

To use the same variable in different modules, you must specify the XDCL and XREF attributes. The XDCL attribute indicates that the variable being declared can be referenced from other modules. The XREF attribute indicates that the variable is declared in another module. When the loader loads modules, it resolves variable declarations so that each XDCL variable is allocated static storage and the XREF variable shares the same space. This is known as "satisfying externals." The loader issues an error if an XREF variable does not have a corresponding XDCL variable. In one compilation unit or group of units that will be combined for execution, a specific variable can have only one declaration that contains the XDCL attribute.

Declarations for a shared variable must match. A variable declared with the XDCL attribute can have different values assigned during program execution. A variable declared with the XREF attribute can also be assigned values.

If any attributes are declared, the variable is assumed to be static in storage. If no attributes are declared, the variable is assumed to be automatic, unless it is declared at the outermost level of the module. (A variable declared at the outermost level is always static.)

Storage

The storage attributes determine when storage is allocated and where storage is allocated.

When Storage Is Allocated

There are two methods of allocating storage for variables: automatic and static. For an automatic variable, storage is allocated when the block containing the variable's declaration begins execution. Storage is released when execution of the block ends. If the block is executed again, storage is allocated again, and so on. When storage is released, the value of the variable is lost.

For a static variable, storage is allocated only once, at load time. Storage remains allocated throughout execution of the module. However, even though storage remains allocated, a static variable still follows normal scope rules. It can be accessed only within the block in which it is declared. A reference to a static variable from an outer block is an error even though storage for the static variable is still allocated.

The ability to declare a static variable is important, for example, in the case where an XDCL variable is referenced by a procedure before the procedure that declares the variable is executed. Because an XDCL variable is static (refer to Scope earlier in this chapter for further information), it is allocated space and at load time; therefore, it is available to be referenced before execution of the procedure that actually declares it as XDCL.

A variable can be declared static explicitly with the STATIC attribute. It is assumed to be static implicitly if it is in the outermost level of a module or if it has any attributes declared. In all other cases, CYBIL assumes the variable is automatic.

The period between the time storage for a variable is allocated and the time that storage is released is called the lifetime of the variable. It is defined in terms of modules and blocks. The lifetime of an automatic variable is the execution of the block in which it is declared. The lifetime of a static variable is the execution of the entire module. An attempt to reference a variable beyond its lifetime causes an error and unpredictable results.

The lifetime of a formal parameter in a procedure is the lifetime of the procedure in which it is a part. Storage space for the parameter is allocated when the procedure is called and released when the procedure finishes executing.

The lifetime of a pointer must be less than or equal to the lifetime of the data to which it is pointing.

The lifetime of a variable that is allocated using the storage management statements (described in chapter 5) is the time between the allocation of storage and the release of storage. A variable allocated by an automatic pointer (using the ALLOCATE statement) must be explicitly freed (using the FREE statement) before the block is left or the space will not be released by the program. When the block is left, the pointer no longer exists and, therefore, the variable cannot be referenced. If the block is entered again, the previous pointer and the variable referenced by the pointer cannot be reclaimed.

Example:

In this example, the variables COUNTER and FLAG will exist during execution of the entire module; however, they can be accessed only within program MAIN.

```
PROGRAM main;
  VAR
    counter : [STATIC] integer,
    flag : [STATIC] boolean;
        .
        .
        .
PROCEND main;
```

Where Storage Is Allocated

You can optionally specify that storage for a variable be allocated in a particular section. A section is a storage area that can hold variables sharing common access attributes, that is, read-only variables or read/write variables. You define the section and its access attributes yourself using the SECTION declaration (discussed later in this chapter).

If you define a section with the section READ attribute, you define a read-only section in the hardware.† Any variable declared with that section's name as an attribute will reside in that read-only section. When you specify the name of a read-only section in a variable declaration, you must also include the variable access attribute READ.

Example:

This example defines a read-only section named NUMBERS. The variable INPUT_NUMBER is a read-only variable that also resides in the section NUMBERS. In the variable declaration, the READ attribute causes the compiler to check that the variable is not written; the read-only section name, NUMBERS, causes the hardware to ensure that the variable is not written.

```
SECTION
  numbers : READ;
VAR
  input_number : [READ, numbers] integer;
```

TYPE DECLARATION

The standard data types that are defined in CYBIL are described in chapter 4. Any of these can be declared as a valid type within a variable declaration. The type declaration allows you to define a new data type and give it a name, or redefine an existing type with a new name. Then that name can be used as a valid type within a variable declaration.

The format of the type declaration is:

TYPE name = type {,name = type}...;

name	Name to be given to the new type.
type	Any of the standard types defined by CYBIL or another user-defined type.

Once you define a type, you can use it to define yet another type. Thus, you can build a very complex type that can be referred to by a single name.

The type declaration is evaluated at compilation time. It does not occupy storage space during execution.

†A read-only section is a hardware feature on some computer systems. Data that resides in a physical area of the machine designated as a read-only section is protected by hardware as opposed to software.

Example:

In this example, INT is defined as a type consisting of all the integers; it is just a shortened name for a standard type. LETTERS is defined as a type consisting of the characters A through Z only; this is a selective subset of the standard type characters. DEVICES is an ordinal type that in turn is used to define EQ_TABLE, a type consisting of an array of 10 elements. Any element in the type EQ_TABLE can have one of the ordinal values specified in DEVICES.

```
TYPE
  int = integer,
  letters = 'a'..'z',
  devices = (lp512, dk844, mt667, nt669),
  eq_table = array [1..10] of devices;

VAR
  i : int,
  alpha : letters,
  table_1 : eq_table,
  status_table : array [1..3] of eq_table;
```

All of the variables in the preceding example could have been declared strictly using variable declarations as in:

```
VAR
  i : integer,
  alpha : 'a'..'z',
  table_1 : array [1..10] of (lp512, dk844, mt667, nt669),
  status_table : array [1..3] of array [1..10] of (lp512, dk844,
    mt667, nt669);
```

However, it becomes quite cumbersome to declare a complex structure using only standard types. Defining your own types lets you avoid needless repetition and the increased possibility of errors. In addition, it makes code easier to maintain; to add a new device, you need add it only in the type declaration, not in every variable declaration that contains devices.

SECTION DECLARATION

A section is an optional working storage area that contains variables with common access attributes. Including the section name in a variable declaration causes the variable to reside in that section.

The format of the section declaration is:

```
SECTION name {,name}... : attribute
        {,name {,name}... : attribute}...;
```

name	Name of the section.
attribute	The keyword READ or WRITE.

A section defined with the READ attribute is considered a read-only section.† A variable declared with that section's name will reside in read-only memory. In this case, the variable access attribute READ must also be included in the variable declaration. The section name causes hardware protection; the READ attribute causes compiler checking.

A section defined with the WRITE attribute contains variables that can be both read and written.

Variables declared with a section name are static.

Example:

Two sections are defined in this example: LETTERS is a read-only section and NUMBERS is a read/write section. The variable CONTROL_LETTER is a read-only variable that resides in LETTERS. The READ attribute is required because of the read-only section name. UPDATE_NUMBER is a variable that can be read or written, and resides in the section NUMBERS. In this example, it is also declared as an XDCL variable but this is not required.

```
SECTION
  letters : READ,
  numbers : WRITE;
VAR
  control_letter : [READ,letters] char,
  update_number : [XDCL,numbers] integer;
```

† A read-only section is a hardware feature on some computer systems. Data that resides in a physical area of the machine designated as a read-only section is protected by hardware as opposed to software.

TYPES 4

There are many standard types defined within CYBIL. A variable can be assigned to (that is, an element of) any of these types. The type defines characteristics of the variable and what operations can be performed using the variable. In general, operations involving nonequivalent types are not allowed; one type cannot be used where another type is expected. Exceptions are noted in the descriptions that follow.

In this chapter, types are grouped into three major categories: basic types, structured types, and storage types.

Basic types are the most elementary. They can stand alone but are also used to build the more complex structures. The basic types are:

- Scalar types (integer, character, boolean, ordinal, and subrange)
- Floating-point types (real)
- Pointer types
- Cell types

Structured types are made from combinations of the basic types. The structured types are:

- Strings
- Arrays
- Records
- Sets

Storage types hold groups of components of various types. The storage types are:

- Sequences
- Heaps

Most types, when they are declared, have a fixed size. Strings, arrays, records, sequences, and heaps can also be declared with an adaptable size that is not fixed until execution. For this reason, they are sometimes called adaptable types. Adaptable strings, arrays, records, sequences, and heaps are discussed at the end of this chapter.

USING TYPES

Types are used as parameters in two kinds of declarations: the variable declaration (to associate a type with a variable name) and the type declaration (to associate a type with a new type name). Both declarations are described in detail in chapter 3, but their basic formats are as follows.

```
VAR name : { [attributes] } type;

TYPE name = type;
```

The description of each type shown in this chapter will give the keyword and any additional information necessary to specify that type as a parameter. They replace the generic word "type" in the variable and type declarations. For example, the keyword to specify an integer type is INTEGER. The variable declaration would be:

```
VAR name : { [attributes] } INTEGER;
```

The type declaration would be:

```
TYPE name = INTEGER;
```

EQUIVALENT TYPES

As mentioned earlier in this chapter, operations involving nonequivalent types are not allowed. Two types can be equivalent, though, even if they don't appear to be identical. For example, two arrays can have different expressions defining their sizes but the expressions may yield the same value. Rules for determining whether types are equivalent are given in the descriptions of the types that follow.

Adaptable types and bound variant record types (described under Records later in this chapter) actually define classes of related types that vary by a characteristic, such as size. Adaptable type variables, bound variant record type variables, and pointers to both types are fixed explicitly at execution time. These types are said to be potentially equivalent to any of the types to which they can adapt. That is, during compilation, references to adaptable types and bound variant record types are allowed wherever there is a reference to one of the types to which they can adapt. However, further type checking is done during execution when each type is fixed (assigned to a specific type). It is the current type of an adaptable or bound variant record type that determines what operations are valid for it at any given time.

BASIC TYPES

The four basic types, scalar, floating-point, pointer, and cell, are described below.

SCALAR TYPES

All scalar types have an order; that is, for every element of a scalar type you can find its predecessor and successor.

Scalar types are made up of five types:

- Integer
- Character
- Boolean
- Ordinal
- Subrange

Integer

The keyword used to specify an integer type is:

    INTEGER

Integers range in value from -2**48 to 2**48.

In general, the subrange type should be used rather than the integer type. This allows the compiler to perform more rigorous type checking and reduces the amount of storage needed to hold the value.

The following operations are permitted on integers: assignment, addition, subtraction, multiplication, division (both quotient and remainder), all relational operations, and set membership. Refer to Operators in chapter 5 for further information on operations.

The functions $INTEGER and $REAL, described in chapter 6, convert between integer type and real type. The $CHAR function, also in chapter 6, converts an integer value between 0 and 255 to a character according to its position in the ASCII collating sequence.

Example:

This example shows the definition of a new type named INT, which consists of elements of the type integer. The variable declaration declares variable I to be of type INT, which is the integer type just declared. Also declared as a variable is NUMBERS, which is explicitly of integer type. It´s possible, however, that because of calculations and assignments made later in the program, MAX could at some time have a value up to -65 535 to 65 535.

```
TYPE
  int = integer;
VAR
  i : int,
  numbers : [STATIC] integer,
  max : [STATIC] integer;
```

Character

The keyword used to specify a character type is:

CHAR

An element of the character type can be any of the characters in the ASCII character set defined in appendix B. It is always a single character; more than one character is considered a string. (A string is a structured type that is discussed later in this chapter. A string of length 1 can sometimes be used as a character. Refer to Substrings later in this chapter.)

The following operations are permitted on characters: assignment, all relational operations, and set membership. Characters can be assigned to and compared to strings. Refer to Operators in chapter 5 for further information on operations and to Strings later in this chapter for further information on string assignment.

The $INTEGER function described in chapter 6 converts a character value to an integer value based on its position in the ASCII collating sequence. The $CHAR function, also in chapter 6, converts an integer value between 0 and 255 to a character in the ASCII collating sequence.

Example:

This example shows the definition of a new type named LETTERS, which consists of elements of character type. The variable declaration declares variable ALPHA to be of LETTERS type, which is character type; it is static. Variable IDS is explicitly declared to be of character type.

```
TYPE
  letters = char;
VAR
  alpha : [STATIC] letters,
  ids : char;
```

Boolean

The keyword used to specify a boolean type is:

BOOLEAN

An element of the boolean type can have one of two values: FALSE or TRUE. As with other scalar types, boolean values are ordered. Their order is FALSE, TRUE. FALSE is always less than TRUE.

You get a boolean value by performing a relational operation on integers, characters, ordinals, floating-point numbers, or boolean values.

The following operations are permitted on boolean values: assignment, all relational operations, set membership, and boolean sum, product, difference, exclusive OR, and negation. Refer to Operators in chapter 5 for further information on operations.

The $INTEGER function described in chapter 6 converts a boolean value to an integer value. Zero (0) is returned for FALSE; one (1) is returned for TRUE.

Example:

This example shows the definition of a new type named STATUS, which consists of the boolean values FALSE and TRUE. The variable declaration declares variable CONTINUE to be of type STATUS; that is, it can be either FALSE or TRUE. The variable DEBUG is explicitly declared to be boolean.

```
TYPE
  status = boolean;
VAR
  continue : status,
  debug : boolean;
```

Ordinal

The ordinal type differs from the other scalar types in that you, the user, define the elements within the type and their order. The term ordinal refers to the list of elements you define; the term ordinal name refers to an individual element within the ordinal.

The format used to specify an ordinal is:

(name, name {,name...})

name — Name of an element within the ordinal. There must be at least two ordinal names.

The order is given in ascending order from left to right.

Each ordinal name can be used in just one ordinal type. If a name is used in more than one ordinal, a compilation error occurs.

Ordinals are used to improve the readability and maintainability of programs. They allow you to use meaningful names within a program rather than, for example, map the names to a set of integers that are then used in the program to represent the names.

The following operations are permitted on ordinals: assignment, all relational operations, and set membership.

Two ordinal types are equivalent if they are defined in terms of the same ordinal type names.

The $INTEGER function described in chapter 6 converts an ordinal value (name) to an integer value based on its position within the defined ordinal.

Examples:

In this example, the type declaration defines a type named COLORS, which is an ordinal that consists of the elements RED, GREEN, and BLUE. The variable PRIMARY_COLORS is of COLORS type and therefore has the same elements. The variable WORK_DAYS explicitly declares the ordinal consisting of elements MONDAY through FRIDAY.

```
TYPE
  colors = (red, green, blue);
VAR
  primary_colors : colors,
  work_days : (monday, tuesday, wednesday, thursday, friday);
```

In the ordinal type COLORS, the following relationships hold:

RED < GREEN

RED < BLUE

GREEN < BLUE

You can find the predecessor and successor of every element of an ordinal. You can also map each element onto an integer using the $INTEGER function (described in chapter 6.) For example, $INTEGER(RED) = 0; this is the first element of the ordinal.

The type declaration

```
TYPE
  primary_colors = (red, green, blue),
  hot_colors = (red, orange, yellow);
```

is in error because the name RED appears in two ordinal definitions.

Subrange

A subrange is not really a new type but a specified range of values within an existing scalar type. A variable defined by a subrange can take on only the values between and including the specified lower and upper bounds.

The format used to specify a subrange is:

lowerbound .. upperbound

lowerbound	Scalar expression specifying the lower bound of the subrange.
upperbound	Scalar expression specifying the upper bound of the subrange.

The lower bound must be less than or equal to the upper bound. Both bounds must be of the same scalar type.

The type of a subrange is the type of its lower and upper bounds. If a subrange completely encompasses its own type, it is said to be an improper subrange type. For example, the subrange

FALSE..TRUE

is of type boolean and also contains every element of type boolean. It is equivalent to specifying the type itself. An improper subrange type is always equivalent to its own type.

Two subranges are equivalent if they have the same lower and upper bounds.

Subranges allow for additional error checking. Compilation options are available that cause the compiler to check assignments during program execution and issue an error if it finds a variable not within range. (Range checking is available as an option on the compiler call command and as a compiler directive. They are both described in section 8. For further information about the compiler call, refer to Compile Time Directives in section 8.) In addition, subranges improve readability. Because a subrange defines the valid range of values for a variable, it is more meaningful to the user for documentation and maintenance.

The operations permitted on a subrange are the same as those permitted on its type (the type of its lower and upper bound).

Example:

This example shows the definition of a new type named LETTERS, which consists of the characters A through Z only. It also defines an ordinal named COLORS consisting of the colors listed. The variable declaration declares variable SCORES to consist of the numbers 0 through 100. The lower and upper bounds are of integer type, so the subrange is also an integer type. STATUS is a subrange of boolean values, which could have been declared simply as BOOLEAN. HOT_COLORS is a subrange of the ordinal type COLORS. It consists of the colors RED, ORANGE, and YELLOW.

```
TYPE
  letters = 'a'..'z',
  colors = (red, orange, yellow, white, green, blue);
VAR
  scores = 0..100,
  status = FALSE..TRUE,
  hot_colors = red..yellow;
```

FLOATING-POINT TYPES

The floating-point type defines real numbers. The keyword used to specify a real type is:

REAL

Real numbers range in value from -2.0**48 to 2.0**48.

The following operations are permitted on real types: assignment, addition, subtraction, multiplication, division, and all relational operations.

The functions $INTEGER and $REAL, described in chapter 6, convert between integer type and real type.

POINTER TYPES

A pointer represents the location of a value rather than the value itself. When you reference a pointer, you indirectly reference the object to which it is pointing.

The format for specifying a pointer type is:

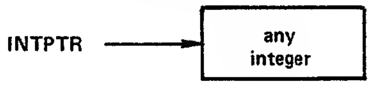
^ type

type — Type to which the pointer can point. It can be any defined type. With the exception of a pointer to cell type (discussed later in this chapter), the pointer can point to objects of this specified type only.

For example,

```
VAR intptr = ^ integer;
```

defines a pointer named INTPTR that can point only to integers.



The format for specifying the object of a pointer (that is, what the pointer points to) is:

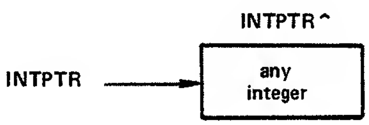
```
pointer_name ^
```

pointer_name   The name you gave the pointer in the variable declaration.

This preceding notation is called a pointer reference; it refers to the object to which pointer_name points. It can also be referred to as a dereference. For example,

```
intptr ^
```

identifies a location in memory; it is the location to which INTPTR points.



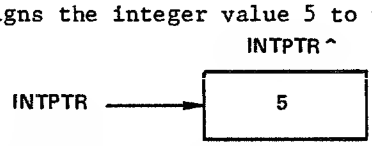
You can assign a value to the object of a pointer as you would any other variable; that is:

```
pointer_name ^ := value;
```

This assigns the specified value to the object that the pointer points to. For example,

```
intptr ^ := 5;
```

assigns the integer value 5 to the location INTPTR points to:



You can assign the object of a pointer to a variable in the same way:

```
variable := pointer_name ^;
```

This takes the value of what pointer_name points to and assigns it to the variable. For example,

```
i := intptr ^;
```

assigns to I the contents of what INTPTR points to, that is, 5.

Pointer to Pointer

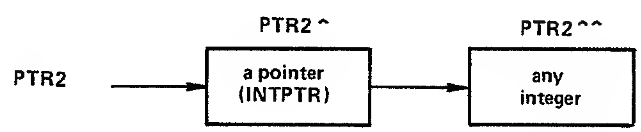
If a pointer reference is to another pointer type variable, meaning that the pointer points to a pointer which in turn points to a variable, you can specify the variable with the form:

```
pointer_name ^^
```

For example, the declarations

```
TYPE
  intptr = ^ integer;
VAR
  ptr2 : ^ intptr;
```

can be pictured conceptually as follows:



PTR2 points to a pointer of type INTPTR. INTPTR points to integers. A reference to PTR2 ^ refers to the location of the pointer that in turn points to an integer. A reference to PTR2 ^^ refers to the location of the integer.

The value assigned to a pointer can be:

- The pointer constant NIL.
- The pointer symbol ^ followed by a variable of the type to which the pointer can point.
- A pointer variable.
- A pointer-valued function.

NIL is the value of a pointer variable without an object; the variable is not currently assigned to any location. It can be assigned to or compared with any pointer of any type.

Pointers allow you to manipulate storage dynamically. Using pointers, you can create and destroy variables while a program is executing. Memory is allocated when the variable is created and released when it is destroyed. Pointers also allow you to reference the variables without giving each a unique name.

A pointer variable can be a component of a structured type as well as a valid parameter in a function. A function can return a pointer variable as a value.

Permissible operations on pointers are assignment and comparison for equality and inequality.

Pointers to adaptable types (adaptable strings, arrays, records, sequences, and heaps) provide the only method for accessing objects of these types other than through formal parameters of a procedure. In particular, pointers to adaptable types and pointers to bound variant records are used to access adaptable variables and bound variant records whose types have been fixed by an ALLOCATE, PUSH, or NEXT statement (described in chapter 5).

Pointers are equivalent if they are defined in terms of equivalent types. A pointer to a fixed type (as opposed to an adaptable type) can be assigned and compared to a pointer to an adaptable type or bound variant record if the adaptable type is potentially equivalent to the fixed type. (Refer to Equivalent Types at the beginning of this chapter for further information on potentially equivalent types.)

Example:

The following example shows the declaration and manipulation of two pointer type variables. Comments appear to the right.

`TYPE ptr = ^integer;` `VAR i, j, k : integer,`	PTR is a type that can contain pointers to integers.
`p1 : ptr,`	P1 is a variable that can contain pointers to integers.
`p2 : ^p1,` `b1, b2 : boolean;`	P2 is a variable that can contain pointers to P1 (that is, pointers that point to pointers to integers). It could have been written as P2 : ^^ INTEGER.
`ALLOCATE p1;`	Allocates space for an integer (because that is what P1 points to) and sets P1 to point to that space.
`ALLOCATE p2;`	Allocates space for a pointer that points to an integer and sets P2 to point to that pointer.
`p1^ := 10;`	The space pointed to by P1 is set to 10.
`p2^ := p1;`	The space pointed to by P2 is set to the value of the pointer P1.
`j := p1^;`	The integer variable J is set to what P1 points to: the integer 10.
`k := p2^^;`	The integer variable K is set to the object of the pointer that P2 points to. (Think of "P2 ^^" as "P2 points to a pointer; that pointer points to an object." You are assigning that object to K.) P2 points to P1, which points to the integer 10.
`b1 := j = k;` `b2 := p1^ = p2^^;`	J and K are both 10. B1 is TRUE. P1 points to an integer. P2 points to the pointer (P1) that points to the same integer. Their values are the same and B2 is TRUE.
`p1 := NIL;`	P1 no longer points to anything.
`k := p1^;`	The statement is in error because P1 does not point to anything.

`IF p2 = NIL THEN`
`  k := k + 1`
`IFEND;`
	A valid statement. K is not incremented because P2 still points to P1.

`p1 := ^(i + j + 2 * k);`	An invalid statement. The location of an expression cannot be found.

Pointer to Cell

A pointer to cell type can take on values of any type.†

The format for declaring a pointer to a cell is:

```
^CELL
```

A variable declared simply as a pointer type variable can take on as values only pointers to a single type, which is specified in the pointer's declaration. A variable declared as a pointer to cell variable has no such restrictions. It can take on values of any type. Also, any fixed or bound variant pointer variable can assume a value of pointer to cell.

Permissible operations on a pointer to a cell are assignment and comparison for equality and inequality. In addition, a pointer to a cell can be assigned to any pointer to a fixed or bound variant type. But the pointer to the fixed or bound variant type cannot have as its value a pointer to a variable that is not a cell type or, furthermore, whose type is not equivalent to the type to which the target of the assignment points. A pointer to a cell can be the target of assignment of any pointer to a fixed or bound variant type.

CELL TYPES

The cell type represents the smallest storage location that is directly addressable by a pointer. On the Control Data 110, a cell is a 16-bit memory word.

The keyword used for specifying a cell type is:

```
CELL
```

Operations permitted on a cell type are assignment and comparison for equality and inequality.

STRUCTURED TYPES

Structured types are combinations of the basic types described previously in this chapter (integer, character, boolean, ordinal, subrange, real, pointer, and cell). Even the structured types discussed here can be combined with each other but they are still essentially groups of the basic types. The structured types described in this chapter are:

- Strings
- Arrays
- Records
- Sets

†A cell is the smallest storage location that can be addressed directly by a pointer. The cell type is discussed later in this chapter.

STRINGS

A string is one or more characters that can be identified and referenced as a whole by one name.

The format used to specify a string type is:

```
STRING (length)
```

length — A positive integer constant expression from 1 to 65 535.

If an initial value is specified in the variable declaration for a string, it can be:

- A string constant.
- The name of a string constant declared with the CONST declaration.
- A constant expression (as described in chapter 2).

A string cannot be packed. Two string types are equivalent if they have the same length.

The following operations are permitted on string types: assignment and comparison (all six relational operations). For further information, refer to Assigning and Comparing String Elements later in this chapter.

Substrings

You can reference a part of a string (this is called a substring) or a single character of a string.

The format for referencing a substring or single character is:

```
name (position {, length})
```

name — Name of the string.

position — Position within the string of the first character of the substring. (The position of the first character of the string is always 1.) It must be a positive integer expression less than or equal to the length of the string plus one; that is,

$$0 < \text{position} \leq \text{string length} + 1$$

If the string length plus one is specified, the substring is an empty string.

length — Number of characters in the substring. It must be a non-negative integer expression or * (the asterisk character). If * is specified, the substring consists of all remaining characters in the string following the "position" character. If zero is specified, the substring is an empty string. If the parameter is omitted, a length of 1 is assumed.

A substring reference in the form

```
name(position)
```

is a substring of length 1, a single character. In this form, it can be used anywhere a character expression is allowed. It can be

- Compared with a character.
- Tested for membership in a set of characters.
- Used as the initial and/or final value in a FOR statement that is controlled by a character variable.
- Used as a value in a CASE statement.
- Used as an argument in the standard functions $INTEGER, SUCC, and PRED.
- Assigned to a character variable.
- Used as an actual parameter to a formal parameter of type character.
- Used as an index value corresponding to a character type index in an array.

A string constant, even if it is declared with a name in a CONST declaration, is not a variable. Therefore, substrings cannot be referenced in a string constant.

Examples:

If a string variable LETTERS is declared as follows:

```
VAR letters : string (6);
```

and initialized at run time to the value ´abcdef´, then the following substring references are valid:

Substring	Comments
LETTERS(1)	Refers to ´a´
LETTERS(6)	Refers to ´f´
LETTERS(1,6)	Refers to the entire string
LETTERS(1,*)	Refers to the entire string
LETTERS(2,5)	Refers to ´bcdef´
LETTERS(2,*)	Refers to ´bcdef´
LETTERS(2,0)	Refers to an empty string ´´
LETTERS(7,*)	Refers to an empty string ´´

LETTERS(0), LETTERS(8) and LETTERS(8,0) are illegal.

If a pointer variable is declared and initialized at run time as follows

```
VAR string_ptr : ^string (6);
.
.
.
string_ptr := ^letters;
```

then STRING_PTR points to the string LETTERS and the pointer variable STRING_PTR^ can be used to make substring references just like the variable LETTERS.

Substring	Comments
STRING_PTR^(1)	refers to 'a'
STRING_PTR^(6)	refers to 'f'
STRING_PTR^(1,6)	refers to the entire string
STRING_PTR^(2,*)	refers to 'bcdef'
STRING_PTR^(2,0)	refers to an empty string ''

Assigning and Comparing String Elements

You can assign or compare a character, substring, or string to a substring, string variable, or character variable. A character is treated as a string of length 1.

If you are assigning a value that is longer than the substring or variable to which it is being assigned, the value is truncated on the right. If you are assigning a value that is shorter, blanks are appended on the right to fill the field. This method is also used for comparing strings of different lengths.

If a substring is being assigned to a substring of the same variable, the fields cannot overlap or the results are undefined.

Examples:

Assume the string variable DAY is declared as follows

```
VAR
  day : string (6);
```

and initialized to the value 'monday'.

The following assignments can be made.

```
short := day (1,3);
empty := day (1,0);
```

SHORT is assigned the string 'mon'. EMPTY is assigned a null string.

ARRAYS

An array in CYBIL is a collection of data of the same type. You can access an array as a whole using a single name or you can access its elements individually.

The format used for specifying an array type is:

```
{PACKED} ARRAY [subscript_bounds] OF type
```

PACKED	Optional packing parameter. When specified, the elements of the array are mapped in storage in a manner that conserves storage space, possibly at the expense of access time. If omitted, the array is unpacked; that is, the elements are mapped in storage to optimize access time rather than conserve space. (The array itself is always mapped into an addressable memory location; that is, it starts on a word boundary or, in the case of a packed array in a record, on a byte boundary.) For further information on how data is stored in memory, refer to appendix D. If the array contains structured types (such as records), the elements of that type (the fields in the records) are not automatically packed. The structured type itself must be declared packed.
subscript_bounds	Value which specifies the size of the array and what values you can use to refer to individual elements. The bounds can be any scalar type or subrange of a scalar type, except REAL; the bounds is often a subrange of integers.
type	Type of the elements within the array. The type can be any defined type, including another array, except an adaptable type (that is, an adaptable string, array, or record). All elements must be of the same type.

Elements of a packed array cannot be passed as reference (VAR) parameters in programs, functions, or procedures.

Two array types are equivalent if they have the same packing attribute, equivalent subscript bounds, and equivalent component types.

The only operation permitted on an array type is assignment.

The array name alone refers to the entire structure. The format for referring to an individual element of an array is:

```
array_name[subscript]
```

subscript	A scalar expression within the range and of the type specified in the subscript_bounds field of the array declaration. This subscript specifies a particular element.

Examples:

This example shows the definition of a type named POS_TABLE, which is an array of 10 elements that can take on the values defined in POSITION. The variable declaration declares variable NUMBERS to be an array of five elements. LETTERS is an array of 26 elements that can be any characters. BIG_TABLE is a 100-element array, of which each element is itself an array of 10 elements.

```
TYPE
  position = (boi, asis, eoi),
  pos_table = array [1..10] of position;
VAR
  i : integer := 5,
  number : array [1..5] of integer,
  letters = array ['a'..'z'] of char,
  big_table = array [1..100] of pos_table;
```

The declaration of BIG_TABLE is equivalent to

```
VAR big_table = array [1..100] of array [1..10] of position;
```

Individual elements can be referenced with the following statements.

`numbers [i]`	This reference is the same as NUMBERS [5]; it refers to the fifth element of the array NUMBERS.
`letters ['b'] := 2;`	This statement sets the second element of the array LETTERS to 2.
`big_table [13][10] := asis;`	This statement sets the tenth element of the thirteenth array to ASIS.

The following example shows the declaration of a two-dimensional array named DATA_TABLE.

```
TYPE
  innerarray = array [1..5] of integer,
  twodim = array [1..4] of innerarray;

VAR
  data_table : twodim;
```

RECORDS

Records are collections of data that can be of different types. You can access a record as a whole using a single name or you can access elements individually.

A record has a fixed number of components, usually called fields, each with its own unique name. Different fields are used to indicate different data types or purposes.

There are two types of records: invariant records and variant records. Invariant records consist of fields that don't change in size or type. Variant records can contain fields that vary depending on the value of a key variable. Formats used for specifying both kinds of records are given later in this chapter.

Operations permitted on record types are assignment and, for invariant records only, comparison for equality and inequality. The invariant records being compared cannot contain arrays as fields.

Invariant Records

An invariant record consists of fields that do not vary in size or type. They are called fixed or invariant fields.

The format used for specifying an invariant record is:

```
    {PACKED} RECORD
             field_name : {ALIGNED {[offset MOD base]}} type
            {,field_name : {ALIGNED {[offset MOD base]}} type}...
    RECEND
```

PACKED — Optional packing parameter. When specified, the fields of a record are mapped in storage in a manner that conserves storage space, possibly at the expense of access time. If omitted, the record is unpacked; that is, the fields are mapped in storage to optimize access time rather than to conserve space. For further information on how data is stored in memory, refer to appendix D.

If one of the fields is a structured type (such as another record), the elements of that type are not packed automatically. The structured type itself must be declared packed.

field_name — Name identifying a particular field. The name must be unique within the record. Outside of the record declaration, it can be redefined.

ALIGNED — Optional alignment parameter. If specified, it can appear alone or with an offset in the form

```
ALIGNED [offset MOD base]
```

When a field is aligned, it is mapped in storage so that it is directly addressable. This means the field begins on an addressable boundary to facilitate rapid access to the field. This may negate some of the effect of packing the record. For further information, refer to Alignment later in this chapter.

offset MOD base — Optional offset to be used in conjunction with the ALIGNED parameter. This offset causes the field to be mapped to a particular hardware address relative to the specified base and offset. It can be a particular word or a particular byte within a word. Base is evaluated first to find the word boundary; offset is then evaluated to determine the number of bytes offset within that word. Filler is created if necessary to ensure that the field begins on the specified word or byte.

- offset — Byte offset within the word specified by base. It must be an integer constant less than base.
- base — Word boundary. It must be an integer constant that is divisible by 8. For automatic variables, the base can only be 8.

type — Any defined type, including another record, but not an adaptable type.

Elements of a packed record cannot be passed as reference (VAR) parameters in programs, functions, or procedures unless they are aligned.

The only operations possible on whole invariant records are assignment and comparison. A record can be assigned to another record if they are both of the same type. A record can also be compared to another record for equality or inequality if they are both of the same type. Invariant record types are the same if they have the same packing attributes, the same number of fields, and corresponding fields have the same field names, same alignment attribute, and equivalent types.

Example:

This example shows the definition of two new types, both records. The record named DATE has three fields that can hold, respectively, the day, month, and year. The record named RECEIPTS appears to contain two fields, NAME and PAYMENT; but PAYMENT is itself a record consisting of the three fields in DATE just described.

```
TYPE
  date = RECORD
           day : 1..31,
           month : string (4),
           year : 1900..2100,
         RECEND,

  receipts = RECORD
               name : string (40),
               payment : date,
             RECEND;
```

Variant Records

A variant record contains fields that may vary in size, type, or number depending on the value of an optional tag field. These different fields are called variant fields or simply variants.

The format used for specifying a variant record is:

```
{PACKED} {BOUND} RECORD
    {fixed_field_name : {ALIGNED {[offset MOD base]}} type}...†

    CASE {tag_field_name : } tag_field_type OF

      = tag_field_value =
        variant_field
     {= tag_field_value =
        variant_field}...
    CASEND
RECEND
```

PACKED — Optional packing parameter. When specified, the fields of a record are mapped in storage in a manner that conserves storage space, possibly at the expense of access time. If omitted, the record is unpacked; that is, the fields are mapped in storage to optimize access time rather than to conserve space. For further information on how data is stored in memory, refer to appendix D.

If a field is a structured type (such as another record), the elements of that type are not packed automatically. The structured type itself must be declared packed.

BOUND — Optional parameter indicating that this is a bound variant record. If specified, the tag_field_name parameter is required. Additional information on bound variant records follows the parameter descriptions.

fixed_field_name — The name of a fixed field (one that does not vary in size) as described under Invariant Records earlier in this chapter. The name must be unique within the record. Outside of the record declaration, it can be redefined. There can be zero or more fixed fields.

ALIGNED — Optional alignment parameter, the same as that for an invariant record. If specified, it can appear alone or with an offset in the form

    ALIGNED [offset MOD base]

When a field is aligned, it is mapped in storage so that it is directly addressable. This means the field begins on an addressable boundary to facilitate rapid access to the field. This may negate some of the effect of packing the record. For further information, refer to Alignment later in this chapter.

†When more than one fixed field is specified, they must be separated by commas.

offset MOD base	Optional offset to be used in conjunction with the ALIGNED parameter, the same as that for an invariant record. This offset causes the field to be mapped to a particular hardware address relative to the specified base and offset. It can be a particular word or a particular byte within a word. Base is evaluated first to find the word boundary; offset is then evaluated to determine the number of bytes offset within that word. Filler is created if necessary to ensure that the field begins on the specified word or byte.
	offset — Byte offset within the word specified by base. It must be an integer constant less than base.
	base — Word boundary. It must be an integer constant that is divisible by 8. For automatic variables, the base can only be 8.
type	Any defined type, including another record, but not an adaptable type.
tag_field_name	Optional parameter specifying the name of the variable that determines the variant. The current value of this variable determines which of the variant fields that follow will actually be used. If omitted, the variant that had the last assignment made to one of its fields is used. This parameter is required if the record is a bound variant record (BOUND is specified). Additional information is given following the parameter descriptions.
tag_field_type	Any scalar type. This type defines the values that the tag_field_value can have.
tag_field_value	A constant scalar expression or subrange. It must be one of the possible values that can be assigned to the variable specified by tag_field_name. It must be of the type and within the range specified by tag_field_type. Specifying a subrange has the same effect as listing each value separately.
variant_field	Zero or more fixed fields of the same form as that shown in the second line of this format. This field exists only if the current value of tag_field_name is the same as that in the tag_field_value associated with the variant_field. The last field can be a variant itself.

The variant fields must follow all invariant (fixed) fields in the record. The field following the reserved word CASE is called the tag_field_name. The tag_field_name can take on different values during execution. When its value matches one of the values specified in a tag_field_value, the variants associated with that tag_field_value are used. Variants themselves consists of zero or more fixed fields optionally followed by another variant. If the last field is itself a variant, it can have another CASE clause, tag_field_name, and so on.

The tag_field_name is an optional field. When it is omitted, no storage is assigned for the tag field. If the record has no tag field, you choose a variant by making an assignment to a subfield within a variant. The variant containing that subfield becomes the currently active variant. In a variant record without a tag field, all fields in a new active variant become undefined except the subfield that was just assigned. An attempt to access a variant field that is not currently active produces undefined results.

Space for a variant record is allocated using the largest possible variant.

Variant record types are equivalent if they have the same packing attribute, their fixed fields are equivalent (as defined for invariant record types), they have the same tag field names, their tag field types are equivalent, their tag field values are the same, and their corresponding variant fields are equivalent.

A bound variant record is specified by including the BOUND parameter; the tag_field_name is also required. A bound variant record type can be used only to define pointers for bound variant record types (that is, bound variant pointers). A variable of this type is always allocated in a sequence or heap, or the run-time stack which is managed by the system.

When allocating a bound variant record, you must specify the tag field values that select the variation of the record. Only the specified space is allocated. The ALLOCATE statement in this case returns a bound variant pointer.

If a formal parameter of a procedure is a variant record type, the actual parameter cannot be a bound variant record type.

A record cannot be assigned to a variable of bound variant record type.

Bound variant record types are equivalent if they are defined in terms of equivalent, unbound records. A bound variant record type is never equivalent to a variant record type.

Example:

This example defines a type named SHAPE, which becomes the type of the tag field, in this case a variable named S. When S is equal to TRIANGLE, the record containing fields SIZE, INCLINATION, ANGLE1, and ANGLE2 is used as if it were the only record available. When the value of S changes, the record variant being used changes also.

```
TYPE
  shape = (triangle, rectangle, circle),
  angle = -180..180,
  figure = RECORD
             x,
             y,
             area : real,
           CASE s : shape OF
           = triangle =
               size : real,
               inclination,
               angle1,
               angle2 : angle,
           = rectangle =
               side1,
               side2 : integer,
               skew,
               angle3 : angle,
           = circle =
               diameter : integer,
           CASEND,
           RECEND;
```

Referencing Elements

The record name alone refers to the entire structure. The format for accessing a field in a record is:

```
record_name.field_name {.sub_field_name}...
```

record_name — Name of the record as declared in the variable declaration.

field_name — Name of the field to be accessed. If the field is an array, a reference to an individual element can also be included using the form

```
field_name[subscript]
```

sub_field_name — Optional field name. This parameter is used if the field previously specified is itself a structured type, for example, another record. If the contained field is an array, a reference to an individual element can be included using the form

```
sub_field_name[subscript]
```

Examples:

The variable PROFILE is a record with the fields described in the record type STATS.

```
TYPE stats = RECORD
  age : 6..66,
  married : boolean,
  date : RECORD
    day : 1..31,
    month : 1..12,
    year : 80..90,
    RECEND,
  RECEND;

VAR profile : stats;
```

The following references can be made to fields.

```
profile.age
profile.married
profile.date.day
profile.date.month
profile.date.year
```

Alignment

Unpacked records and their fields are always aligned (that is, directly addressable). Even if it is packed, a record itself is always aligned (that is, the first field is directly addressable) unless it is an unaligned field within another packed structure. Fields in a packed record, however, are not aligned unless the ALIGNED attribute is explicitly included. Aligning the first field of a record aligns the entire record.

Unpacked records and their fields, because they are aligned, can always be passed as reference (VAR) parameters in programs, functions, and procedures. Packed records must be aligned to be valid as reference parameters. Packed, unaligned records cannot be used.

SETS

A set is a collection of elements that, unlike arrays and records, is always operated on as a single unit. Individual elements are never referenced.

The format used to specify a set type is:

```
SET OF scalar_type
```

scalar_type	Type of all elements that will be within the set. It can be a scalar type or a subrange of a scalar type.

All members of a set must be of the same type. Members within a set have no specific order; that is, order has no effect in any of the operations performed on sets.

Set types are equivalent if their elements have equivalent types.

Permissible operations on sets are assignment, intersection, union, difference, symmetric difference, negation, inclusion, identity, and membership. Refer to Operators in chapter 5 for further information on set operations. The SUCC and PRED functions are not defined for set types.

The difference (-) or symmetric difference (XOR) of two identical sets is the empty set. The empty set is contained in any set. For a given set, the complement of the empty set, -[ ], is the full set.

A set value constructor is used for assignment during program execution.

A set value constructor constructs a set through explicit assignment. A set value constructor has the form:

```
$name [ { value {,value}...} ]
```

name	Name of the set as declared in the variable declaration. The dollar sign symbol ($) is required in front of the name to indicate a set value constructor.
value	An expression of the same type as that specified for the set. The empty set can be specified by [ ].

A set value constructor can be used wherever an expression can be used.

Example:

This example shows the declaration of a variable named ODD that is a type of a set of integers from 0 to 10. The variable VOWELS is a set that can contain any of the letters A through Z. It is assigned the letters A, E, I, O, and U using a set value constructor. It constructs a set of type C, which contains the specified letters; then that set is assigned to the set VOWELS.

```
TYPE
  a = set of 0..10,
  c = set of 'a'..'z';

VAR
  odd : a,
  vowels : c;
    .
    .
    .
vowels := $c['a', 'e', 'i', 'o', 'u'];
```

STORAGE TYPES

Storage types represent structures to which variables can be added, deleted, and referenced under program control. (The statements used to access the storage types are described under Storage Management Statements in chapter 5.) There are two storage types:

- Sequences
- Heaps

SEQUENCES

A sequence type is a storage structure whose components are referenced sequentially using pointers. These pointers are constructed by the NEXT and RESET statements (described in chapter 5).

The format used for specifying a sequence type is:

SEQ ({REP number OF} type {,{REP number of} type}...)

number — Positive integer constant expression. This is an optional parameter specifying the number of repetitions of the specified type.

type — A fixed type that can be a user-defined type name; one of the predefined types integer, character, boolean, real, or cell; or a structured type using the preceding types.

The phrase "REP number OF type" can be repeated as many times as desired. It specifies that storage must be available to hold the indicated number of occurrences of the named types simultaneously. The types that are actually stored in a sequence do not have to be the same as the types specified in the declaration, but adequate space must have been allocated to hold those types in the declaration. In other words, if a sequence is declared with several repetitions of integer type, the space to hold these integers has to be available, but it might actually hold strings or boolean values.

Sequence types are equivalent if they have the same number of REP phrases and corresponding phrases are equivalent. Two REP phrases are equivalent if they have the same number of repetitions of equivalent types.

The operation permitted on sequences is assignment to another sequence.

HEAPS

A heap type is a storage structure whose components are allocated explicitly by the ALLOCATE statement and released by the FREE and RESET statements (described in chapter 5). They are referenced by pointers constructed by the ALLOCATE statement.

The format used for specifying a heap type is:

```
HEAP ({REP number OF} type {,{REP number of} type}...)
```

number — Positive integer constant expression. This is an optional parameter specifying the number of repetitions of the specified type.

type — A fixed type that can be a user-defined type name; one of the predefined types integer, character, boolean, real, or cell; or a structured type using the preceding types.

The phrase "REP number OF type" can be repeated as many times as desired. It specifies that storage must be available to hold the indicated number of occurrences of the named types simultaneously. The types that are actually stored in a heap do not have to be the same as the types specified in the declaration but adequate space must have been allocated to hold those types in the declaration. In other words, if a heap is declared with several repetitions of integer type, the space to hold these integers has to be available but it might actually hold strings or boolean values.

Heap types are equivalent if they have the same number of REP phrases and corresponding phrases are equivalent. Two REP phrases are equivalent if they have the same number of repetitions of equivalent types.

The default heap can be managed with the ALLOCATE and FREE statements in the same way as a user-defined heap. For further information, refer to the descriptions of these statements in chapter 5.

ADAPTABLE TYPES

An adaptable type is a type that has indefinite size or bounds; it adapts to data of the same type but of different sizes and bounds. The types described thus far in this chapter are fixed types. An adaptable type differs from a fixed type in that the storage required for a fixed type is constant and can be determined before execution. Storage for an adaptable type is determined during program execution.

An adaptable type can be a string, array, record, sequence, or heap. An adaptable type can be used to define formal parameters in a procedure and adapatable pointers. Pointers are the mechanism used for referencing adaptable variables.

The size of an adaptable type must be fixed during execution. This can be done in one of three ways:

- If the adaptable type is a formal parameter to a procedure or function, the size is fixed by the actual parameters when the procedure or function is called. You can determine the length of an actual parameter string using the STRLENGTH function, and the bounds of an actual parameter array using the UPPERBOUND and LOWERBOUND functions. (For further information, refer to the description of the appropriate function in chapter 6.) All three functions return integer values.

- An adaptable pointer type on the left side of an assignment statement is fixed by the assignment operation. It can be assigned any pointer whose current type is one of the types which the adaptable type can take on.

- An adaptable type can be fixed explicitly using the storage management statements (described in chapter 5).

An adaptable type is declared with an asterisk taking the place of the size or bounds normally found in the type or variable declaration.

ADAPTABLE STRINGS

The format used for specifying an adaptable string is:

STRING (* {<= length})

length	Optional parameter specifying the maximum length of the adaptable string. If omitted, 65 535 characters is assumed.

If the string exceeds the maximum allowable length, an error occurs.

Two adaptable string types are always equivalent.

ADAPTABLE ARRAYS

The format used for specifying an adaptable array is:

```
{PACKED} ARRAY [{lower_bound ..} *] OF type
```

PACKED	Optional packing parameter. When specified, the elements of the array are mapped in storage in a manner that conserves storage space, possibly at the expense of access time. If omitted, the array is unpacked; that is, the elements are mapped in storage to optimize access time rather than to conserve space. (The array itself is always mapped into an addressable memory location.) For further information on how data is stored in memory, refer to appendix D. If the array contains structured types (such as records), the elements of that type (the fields in the records) are not automatically packed. The structured type itself must be declared packed.
lower_bound	A constant integer expression that specifies the lower bound of the adaptable array. This parameter is optional but its use is encouraged. Omission of this parameter (only the * appears) indicates it is an adaptable bound of type integer.
type	Type of the elements within the array. The type can be any defined type except an adaptable type (that is, an adaptable string, array, record, sequence, or heap). All elements must be of the same type.

Only one dimension can be adaptable in an array and that dimension must be the outermost (first one in the declaration).

Adaptable arrays adapt to a specific range of subscripts. An adaptable array can adapt to any array with the same packing attribute, equivalent subscript bounds, and equivalent component types. If a lower bound is specified in the adaptable array declaration, both arrays must also have the same lower bound.

Adaptable array types are equivalent if they have the same packing attributes and equivalent component types, and if their corresponding array and component subscript bounds are equivalent. Two subscript bounds that contain asterisks only are always equivalent. Two subscript bounds that contain identical lower bounds are equivalent.

ADAPTABLE RECORDS

An adaptable record contains zero or more fixed fields followed by one adaptable field that is a field of an adaptable type.

The format used for specifying an adaptable record is:

```
{PACKED} RECORD

    {fixed_field_name : {ALIGNED {[offset MOD base]}} type}...†

    adaptable_field_name : {ALIGNED {[offset MOD base]}} adaptable_type

RECEND
```

PACKED	Optional packing parameter. When specified, the fields of a record are mapped in storage in a manner that conserves storage space, possibly at the expense of access time. If omitted, the record is unpacked; that is, the fields are mapped in storage to optimize access time rather than to conserve space. For further information on how data is stored in memory, refer to appendix D. If a field is a structured type (such as another record), the elements of that type are not packed automatically. The structured type itself must be declared packed.
fixed_field_name	Name identifying a particular fixed field. The name must be unique within the record.
ALIGNED	Optional alignment parameter. If specified, it can appear alone or with an offset in the form ALIGNED [offset MOD base] When a field is aligned, it is mapped in storage so that it is directly addressable. This means the field begins on an addressable boundary to facilitate rapid access to the field. This may negate some of the effect of packing the record. For further information, refer to Alignment earlier in this chapter.
offset MOD base	Optional offset to be used in conjunction with the ALIGNED parameter. This offset causes the field to be mapped to a particular hardware address relative to the specified base and offset. Filler is created if necessary to ensure that the field begins on the specified addressable unit. offset — An integer constant. Offset must be less than base. base — An integer constant that must be divisible by 8. For automatic variables, the base can only be 8.

†If more than one fixed (nonadaptable) field is specified, they must be separated by commas.

type	Any defined type, including another record, but not an adaptable type.
adaptable_field_name	Name identifying the adaptable field.
adaptable_type	An adaptable type.

An adaptable record can adapt to any record whose types are the same except for the last field. That last field must be one to which the adaptable field can adapt.

Two adaptable record types are equivalent if they have the same packing attributes, the same alignment, the same number of fields, and corresponding fields with identical names and equivalent types.

ADAPTABLE SEQUENCES

The format used for specifying an adaptable sequence is:

```
SEQ (*)
```

An adaptable sequence can adapt to a sequence of any size.

Two adaptable sequence types are always equivalent.

ADAPTABLE HEAPS

The format used for specifying an adaptable heap is:

```
HEAP (*)
```

An adaptable heap can adapt to a heap of any size.

Two adaptable heap types are always equivalent.

EXPRESSIONS AND STATEMENTS 5

EXPRESSIONS

Expressions are made up of operands and operators. Operators act on operands to produce new values. (Constant expressions are evaluated to provide values for constants. Refer also to Constant Expressions in chapter 2.)

In general, operations involving nonequivalent types are not allowed; one type cannot be used where another type is expected. Exceptions are noted in the following descriptions.

OPERANDS

Operands hold or represent the values to be used during evaluation of an expression. An operand can be a variable, constant, name of a constant, set value constructor, function reference (either standard function or user-defined function), pointer to a procedure name, pointer to a variable, or another expression enclosed in parentheses.

The value of a variable being used as an operand is the last value assigned to it. A constant name is replaced by the constant value associated with it in the CONST declaration.

A function reference causes the function to be executed; the value returned by the function takes the place of the function reference in the expression.

OPERATORS

Operators cause an action to be performed on one operand or a pair of operands. Many of the operators can be used only on basic types; they will be noted in their individual descriptions. Some operators can be used on sets. Although they are discussed in the individual descriptions that follow, there is also a separate description in this chapter on set operations.

An operation on a variable or component of a variable that has an undefined value will produce an undefined result.

There are five kinds of operators, many of which are identified by reserved symbols. They are listed here in the order in which they are evaluated from highest to lowest precedence.

- Negation operator (NOT)
- Multiplication operators (* , DIV, / , MOD, and AND)
- Sign operators (+ and -)
- Addition operators (+ , - , OR, and XOR)
- Relational operators (< , <= , > , >= , = , <> , and IN)

In the relational operators that consist of two symbols (that is, <=, >=, and <>), the symbols cannot be separated by a space or any other character; they must appear together.

When an expression contains two or more operators of the same precedence, operations are performed from left to right. The only way to explicitly change the order of evaluation is to use parentheses. Parentheses indicate that the expression inside them should be evaluated first.

Negation Operator

The negation operator, NOT, applies only to boolean operands.

NOT TRUE equals FALSE. NOT FALSE equals TRUE.

Multiplication Operators

The multiplication operators perform multiplication and set intersection (*), integer quotient division (DIV), real quotient division (/), remainder division (MOD), and the logical AND operation (AND). Table 5-1 shows the multiplication operators, the permissible types of their operands, and the type of result they produce.

Table 5-1. Multiplication Operators

Operator	Operation	Type of Operands	Type of Result
*	Multiplication	Integer or subrange of integer	Integer
		Real	Real
*	Set intersection	Set of a scalar type	Set of the same type
DIV	Integer quotient†	Integer or subrange of integer	Integer
/	Real quotient	Real	Real
MOD	Remainder function††	Integer or subrange of integer	Integer
AND	Logical AND†††	Boolean	Boolean

† Integer quotient refers to the whole number that results from a division operation. The remainder is ignored. A more formal definition is: for positive integers a, b, and n,

```
a DIV b = n
```

where n is the largest integer such that b * n <= a.

For one or two negative integers,

```
(-a) DIV b = (a) DIV (-b) = - (a DIV b) and
(-a) DIV (-b) = a DIV b
```

†† Remainder function refers to the remainder of a division operation. A more formal definition is:

```
a MOD b = a - (a DIV b) * b
```

```
TRUE AND FALSE = FALSE
TRUE AND TRUE = TRUE
FALSE AND FALSE = FALSE
FALSE AND TRUE = FALSE
```

††† When the first operand is FALSE, the second operand is never evaluated.

Sign Operators

The sign operators perform the identity operation (+) and sign inversion and set complement operation (-). Table 5-2 shows the sign operators, the permissible types of their operands, and the type of result they produce.

Table 5-2. Sign Operators

Operator	Operation	Type of Operands	Type of Result
+	Identity (Indicates a positive operand)	Integer	Integer
		Real	Real
-	Sign inversion (indicates a negative operand)	Integer	Integer
		Real	Real
-	Set complement	Set of a scalar type	Set of the same type

Addition Operators

The addition operators perform addition and set union (+), subtraction, boolean difference, and set difference (-), the logical OR operation (OR), and the exclusive OR operation (XOR). Table 5-3 shows the addition operators, the permissible types of their operands, and the type of result they produce.

Table 5-3. Addition Operators

Operator	Operation	Type of Operands	Type of Result
+	Addition	Integer or subrange of integer	Integer
		Real	Real
+	Set union	Set of a scalar type	Set of the same type
-	Subtraction	Integer or subrange of integer	Integer
		Real	Real
-	Boolean difference†	Boolean	Boolean
-	Set difference	Set of a scalar type	Set of the same type
OR	Logical OR††	Boolean	Boolean
XOR	Exclusive OR†††	Boolean	Boolean
	Symmetric difference	Set of a scalar type	Set of the same type

† TRUE - TRUE = FALSE
TRUE - FALSE = TRUE
FALSE - TRUE = FALSE
FALSE - FALSE = FALSE

†† TRUE OR TRUE = TRUE
TRUE OR FALSE = TRUE
FALSE OR TRUE = TRUE
FALSE OR FALSE = FALSE

When the first operand is TRUE, the second operand is never evaluated.

††† TRUE XOR TRUE = FALSE
TRUE XOR FALSE = TRUE
FALSE XOR TRUE = TRUE
FALSE XOR FALSE = FALSE

Relational Operators

The relational operators test for the truth or falsity of given conditions: less than (<), less than or equal to or subset of a set (<=), greater than (>), greater than or equal to or a superset of a set (>=), equal to or set identity (=), not equal to or set inequality (<>), and set membership (IN).

Because relational operators are valid on so many different types, some special points should be noted for each type. Following these comments, table 5-4 shows the relational operators and the permissible types of their operands; they always produce a boolean type result.

Comparison of Scalar Types

The comparison operators (< , <= , > , >= , = , and <>) are allowed only between operands of the same scalar type or between a substring of length 1 and a character.

For integer type operands, the relationships all have their usual meaning.

For character type operands, each character is essentially mapped to its corresponding integer value according to the ASCII collating sequence. (This is the same operation performed by the $INTEGER function described in chapter 6.) The operands and relational operators are then evaluated using the characters' integer values.

For boolean type operands, FALSE is always considered to be less than TRUE.

For ordinal type operands, operands are equal only if they are the same value; otherwise, they are not equal. For the other relational operators, each ordinal is essentially mapped to the corresponding integer value of its position in the ordinal list where it is defined. (This is the same operation performed by the $INTEGER function described in chapter 6.) The operands and relational operators are then evaluated using the ordinals' integer values. For an example, refer to the discussion of ordinal types in chapter 4.

Operands that are a subrange of a scalar type can be compared with operands of the same type, including another subrange of the same type.

Table 5-4. Relational Operators

Operator	Operation	Type of Left Operand	Type of Right Operand
< <=	Less than Less than or equal to	Any scalar type	The same scalar type
> >=	Greater than Greater than or equal to	A string	A string of the same length
= <>	Equal to Not equal to	A string of length 1 † A character	A character A string of length 1 †
IN	Set membership	Any scalar type	A set of the same type
		A string of length 1 †	A set of character type
=	Equality (also called identity)	A set of any scalar type	A set of the same type
<>	Inequality		
<=	Is contained in		
>=	Contains		
= <>	Equality Inequality	A nonvariant record type containing no arrays	The same type
		Any pointer type or or the value NIL	The same type or the value NIL

† The string of length 1 has the form

    STRING(position)

where the length is implied. The form

    STRING(position,1)

is not valid in this case.

Comparison of Floating-Point Types

All of the comparison operators are valid between operands of real type.

Comparison of Pointer Types

Two pointers can be compared if they are pointers to equivalent or potentially equivalent types. (For further information on equivalent types, refer to Equivalent Types in chapter 4.) For potentially equivalent types, one or both of the pointers can be pointers to adaptable or bound variant types. The current type of such a pointer must be equivalent to the type of the pointer with which it is being compared; if it is not, the operation is undefined.

Pointers can be compared for equality and inequality only. Two pointers are equal if they designate the same variable or if they both have the value NIL. A pointer of any type can be compared with the value NIL. Two pointers to a procedure are equal if they designate the same declaration of a procedure.

Comparison of String Types

All of the comparison operators are valid between operands that are strings. If the lengths of the two string operands are unequal, blanks are appended to the right of the shorter string to fill the field. Strings are compared character by character from left to right; that is, each character from one string is compared with the character in the corresponding position of the second string. Each character is compared using the same method as for operands of character type; the integer value of the character when mapped to the ASCII collating sequence is used.

Comparison of Sets and Set Membership

Comparison operators have slightly different meanings for sets than for other types. The only comparison operators valid for sets are = (meaning identical to), <> (meaning different from), <= (meaning the left operand is contained in the right operand), and >= (meaning the left operand contains the right operand). These operators are valid between two sets of the same type. Their exact meanings are explained in more detail later in this chapter under Set Operators.

The other relational operator for sets is IN. A specified operand is IN a set if that operand is a member of the set. The set must be the same type or a subrange of the same type as the operand. The operand can be a subrange of the type of the set.

Comparison of Other Types

Invariant records can be compared for equality and inequality only. Two equivalent records are equal if their corresponding fields are equal.

The following types cannot be compared.

- Arrays or structures that contain an array as a component or field
- Variant records
- Sequences
- Heaps
- Records that contain a field of one of the preceding types.

However, pointers to these types can be compared.

Set Operators

The set operators have already been mentioned briefly in the preceding sections on multiplication, sign, addition, and relational operators. This section discusses them all together and gives more detail as to how they are used with sets specifically.

The set operators perform assignment, union (+), intersection (*), difference (-), symmetric difference (XOR), negation (-), identity or equality (=), inequality (<>), inclusion (<=), containment (>=), and membership (IN).

Assignment is discussed under Sets in chapter 4. The next five operations (union, intersection, difference, symmetric difference, and negation) all produce results that are sets. They are described in table 5-5.

The remaining operations (identity, inequality, inclusion, containment, and membership) produce boolean results. They are described in table 5-6.

The relational operations described in table 5-6 take place only after any operations described in table 5-5 have been performed.

Table 5-5. Operations That Produce Sets

Operator	Operation	Description of Operation
+	Union	The resulting set consists of all members of both sets. The result of A + B is all elements of sets A and B.
-	Difference	The resulting set consists of the members in the lefthand set that are not in the righthand set. The result of A - B is the elements of A that are not in B. This operation differs from negation in that two operands are present.
*	Intersection	The resulting set consists of the members that are in both sets. The result of A * B is all elements that are in both A and B.
-	Negation (complement)	The resulting set consists of the members of the set´s type that are not in the set. The result of -A is all elements of A´s type that are not in A. This operation differs from the difference operation in that only one operand is present.
XOR	Symmetric difference	The resulting set consists of the members of either but not both sets. The result of A XOR B is all elements in A or B that are not common to both A and B.

Table 5-6. Operations That Produce Boolean Results

Operator	Operation	Description of Operation
=	Equality (identity)	The resulting value is TRUE if every member of one set is present in the other set and vice versa. A = B is TRUE if every element of A is in B and every element of B is in A. It is also TRUE if A and B are both empty sets. In any other case, it is FALSE.
<>	Inequality	The resulting value is TRUE if not every member of one set is a member of the other set. A <> B is TRUE if A = B is FALSE.
<=	Inclusion	The resulting value is TRUE if every member of the left-hand set is also a member of the right-hand set. A <= B is TRUE if every element of A is in B. It is also TRUE if A is an empty set. In all other cases, it is FALSE.
>=	Containment	The resulting value is TRUE if every member of the right-hand set is also a member of the left-hand set. A >= B is TRUE if every element of B is in A (that is, B <= A).
IN	Membership	This operation differs somewhat from the others in that it can specify as an operand a value or a variable rather than a set. It has the form scalar IN set where scalar can be a value (including a subrange) or a variable. The resulting value is TRUE if the scalar is of the same type as the type of the set, and is an element within the set. A IN B is TRUE if A is the same type as the set B and A is an element of B.

STATEMENTS

Statements indicate actions to be performed. Unlike declarations, statements can be executed. They can appear only in a program, procedure, or function.

A statement list is an ordered sequence of statements. In a statement list, a statement is separated from the one following it by a semicolon. Two consecutive semicolons indicate an empty statement. It indicates no action.

Statements can be divided into four types depending on their purpose or nature:

- Assignment
- Structured
- Control
- Storage management

ASSIGNMENT STATEMENT

The assignment statement assigns a value to a variable.

The format of the assignment statement is:

```
name := expression
```

name	Name of a variable previously declared.
expression	An expression that follows the rules stated earlier in this chapter. Any constant or variable contained in the expression must be defined and have a value assigned.

This statement is where you can assign an initial value to a variable. The assignment statement allows you to change that value at any point in the program. The expression is evaluated and the result becomes the current value of the named variable.

The variable cannot be:

- A read-only variable.
- A formal value parameter of the procedure that contains the assignment statement.
- A bound variant record.
- The tag field name of a bound variant record.
- A heap.
- An array or record that contains a heap.

The type of the expression must be equivalent to the type of the variable with the exceptions discussed next. Both types can be subranges of equivalent types.

A character, string, or substring variable can be assigned the value of a character expression, a string, or a substring. If you assign a value that is shorter than the variable or substring to which it is being assigned, blanks are added to the right of the shorter string to fill the field. If you assign a value that is longer than the variable or substring, the value is truncated on the right. Assigning strings or substrings that overlap is not a valid operation (for example, STRING_1 := STRING_1(3,7); results are unpredictable.

If the variable is a pointer, its scope must be less than or equal to the scope of the data to which it is pointing. For example, a static pointer variable should not point to an automatic variable local to a procedure. When the procedure is left, the pointer variable will be pointing at undefined data.

A pointer to a bound variant record can be assigned a pointer to a variant record that is not bound and is otherwise equivalent.

An adaptable pointer can be assigned either a pointer to a type to which it can adapt, or an adaptable pointer than has been adapted to one of those types. Both the type of the expression and its value are assigned, thus setting the current type of the adaptable pointer.

Any fixed pointer except a pointer to sequence can be assigned a pointer to cell. After the assignment, the #LOC function (described in chapter 6) performed on the fixed pointer would return the same value as the pointer to cell.

A pointer to cell can be assigned any pointer type. The value assigned is a pointer to the first cell allocated for the variable to which the pointer being assigned points.

When assigning pointers, remember that generally the object of a pointer has a different lifetime than the pointer variable. Automatic variables are released when the block in which they are declared is through being executed. Allocated variables no longer exist when they are explicitly released with the FREE statement. An attempt to reference a nonexistent variable beyond its lifetime causes an error and unpredictable results to occur.

A variant record can be assigned a bound variant record of types that are otherwise equivalent.

The colon (:) and equals sign (=) together are called the assignment operator. When used as the assignment operator, there can be no spaces or comments between the two symbols.

STRUCTURED STATEMENTS

A structured statement is one that actually contains one or more statements. The statements contained in a structured statement are called collectively a statement list. The structured statement determines when the statement list contained in it will be executed.

There are four structured statements:

BEGIN	Provides a logical grouping of statements that perform a specific function.
FOR	Executes a list of statements while a variable is incremented or decremented from an initial value to a final value.

REPEAT — Executes a list of statements until a specified condition is true. The test is made after each execution of the statements.

WHILE — Executes a list of statements while a specified condition is true. The test is made before each execution of the statements.

BEGIN Statement

The BEGIN statement executes a single statement list once; there is no repetition. This statement provides for a logical grouping of statements that perform a particular function and can improve readability.

The format of the BEGIN statement is:

```
{/label/}
BEGIN
    statement list;
END {/label/};
```

label — Name that identifies the BEGIN statement and the statement list within it. Use of labels is optional. If a label is used before BEGIN, it is not required after END but is encouraged. If labels are used in both places, they must match. The label name must be unique within the block in which it is used.

statement list — One or more statements.

Declarations are not allowed within the BEGIN statement. Execution of the BEGIN statement ends when either the last statement in the list is executed or control is explicitly transferred from within the list.

FOR Statement

The FOR statement executes a statement list repeatedly as a special variable ranges from an initial value to a final value. There are two formats for the FOR statement: one that increments the variable and one that decrements the variable.

The format that increments the variable is:

```
{/label/}
FOR name := initial_value TO final_value DO
    statement list;
FOREND {/label/};
```

The format that decrements the variable is:

```
{/label/}
FOR name := initial_value DOWNTO final_value DO
    statement list;
FOREND {/label/};
```

label	Name that identifies the FOR statement and the statement list in it. Use of labels is optional. If a label is used before FOR, it is not required after FOREND but is encouraged. If labels are used in both places, they must match. The label name must be unique within the block in which it is used.
name	Name of the variable that controls the number of repetitions of the statement list. It keeps track of the number of iterations performed or the current position within the range of values.
initial_value	Scalar expression specifying the initial value assigned to the variable.
final_value	Scalar expression specifying the final value to be assigned to the variable if the statement ends normally. If the statement ends abnormally or as the result of an EXIT statement, this may not be the actual final value.
statement list	One or more statements.

The variable, initial value, and final value must be of equivalent scalar types or subranges of equivalent types. The variable cannot be assigned a value within the statement list, or be passed as a reference parameter to a procedure called within the statement list. Either condition causes a fatal compilation error. The variable cannot be an unaligned component of a packed structure.

When CYBIL encounters a FOR statement that increments (one containing the TO clause), it evaluates the initial value and final value. If the initial value is greater than the final value, the FOR statement ends and execution continues with the statement following FOREND; the statement list is not executed. If the initial value is less than or equal to the final value, the initial value is assigned to the control variable and the statement list is executed. Then the control variable is incremented by one value and, for each increment, the statement list is executed. This sequence of actions continues through the final value. For example, the statement

```
FOR i = 1 TO 5 DO
    .
    .
    .
FOREND;
```

causes the statement list to be executed five times, that is, while I takes on values from 1 through 5. Then the FOR statement ends and execution continues with the statement following FOREND.

When CYBIL encounters a FOR statement that decrements (one containing the DOWNTO clause), it performs essentially the same process. If the initial value is less than the final value, the FOR statement ends and execution continues with the statement following FOREND. If the initial value is greater than or equal to the final value, the initial value is assigned to the control variable and the statement list is executed. The control variable is then decremented by one value and, for each decrement, the statement list is executed. When the control variable reaches the final value and the statement list is executed the last time, the FOR statement ends.

The initial value and final value expressions are evaluated once, when the statement is entered; the values are held in temporary locations. Thus, subsequent assignments to initial value and final value have no effect on the execution of the FOR statement.

When a FOR statement completes normally, the value of the control variable is that of the final value specified in the statement. This may not be the case if the statement ends abnormally or as a result of an EXIT statement.

Example:

FOR statements are often thought of using integer values, but any scalar type can be used. The following example executes a statement list while the value of a character variable is incremented.

```
FOR control := 'a' TO 'z' DO
    .
    .
    .
FOREND;
```

Each time the statement list is performed, the value of CONTROL increases by one value, following the normal sequence of alphabetic characters from A to Z; that is, after the statement list is executed once, the value of CONTROL changes to B, and so on until the list has been executed 26 times.

REPEAT Statement

The REPEAT statement executes a statement list repeatedly until a specific condition is true.

The format of the REPEAT statement is:

```
{/label/}
REPEAT
    statement list;
UNTIL expression;
```

label	Name that identifies the REPEAT statement and the statement list in it. Use of the label before REPEAT is optional; a label is not permitted after UNTIL. The label name must be unique within the block in which it is used.
statement list	One or more statements.
expression	A boolean type expression.

The statement list is always executed at least once. After the last statement in the list, the expression is evaluated. Every time the expression is FALSE, the statement list is executed again. When the expression is TRUE, the REPEAT statement ends and execution continues with the statement following the UNTIL clause.

The statement list can contain nested REPEAT statements.

Example:

In this example, the statement list (mod operation and assignments) is executed once. If J is not equal to zero, it is executed again and continues until J is equal to zero.

```
REPEAT
  k := i MOD j;
  i := j;
  j := k;
UNTIL j = 0;
```

WHILE Statement

The WHILE statement executes a statement list repeatedly while a specific condition is true.

The format of the WHILE statement is:

```
{/label/}
WHILE expression DO
    statement list;
WHILEND {/label/};
```

label	Name that identifies the WHILE statement and the statement list in it. Use of labels is optional. If a label is used before WHILE, it is not required after WHILEND but is encouraged. If labels are used in both places, they must match. The label name must be unique within the block in which it is used.
expression	A boolean type expression.
statement list	One or more statements.

If the boolean expression is evaluated as TRUE, the statement list is executed. After the last statement in the list, the expression is again evaluated. Every time the expression is TRUE, the statement list is executed. When the expression is FALSE, the WHILE statement ends and execution continues with the statement following WHILEND. If the expression is FALSE in the initial evaluation, the statement list is never executed.

Example:

In this example, the expression TABLE[I] <> 0 is evaluated; an element of the array TABLE is compared to zero. While the expression is true (the element is not zero), I is incremented. This causes the next element of the array to be checked. When the expression is false, the statement list is not executed. Execution continues with the statement following WHILEND. I is the position of an element in the array that is zero.

```
/check_for_zero/
  WHILE table[i] <> 0 DO
    i := i + 1;
  WHILEND /check_for_zero/;
```

The preceding example assumes of course that the array does contain an element with the value zero. If not, the WHILE statement list executes in an infinite loop. In either the WHILE expression or the statement list, there must be a check. One solution is to set a variable, TABLE_MAX, to the maximum number of elements in the array and check it before executing the statement list, as in

```
WHILE (i < table_max) AND (table[i] <> 0) DO
```

Now both expressions must be true before the statement list is executed. If either is false, execution continues following WHILEND.

CONTROL STATEMENTS

A control statement can change the flow of execution of a program by transferring control from one place in the program to another.

There are five control statements:

IF	Executes one statement list if a given condition is true; ends the statement or executes another statement list if the condition is false.
CASE	Executes one statement list out of a set of statement lists depending on the value of a given expression.
CYCLE	Causes the remaining statements in a repetitive statement (FOR, REPEAT, or WHILE) to be skipped and the next iteration of the statement to take place.
EXIT	Unconditionally stops execution within a procedure, function, or a structured statement (BEGIN, REPEAT, WHILE, and FOR).
RETURN	Returns control from a procedure or function to the point at which it was called.

Procedure and function calls also transfer control of an executing program. Functions are discussed in chapter 6 and procedures are discussed in chapter 7.

IF Statement

The IF statement executes or skips a statement list depending on whether a given condition is true or false.

The format of the IF statement is:

```
IF expression THEN
   statement list;
{ELSEIF expression THEN
   statement list;}...
{ELSE
   statement list;}
IFEND;
```

expression — A boolean expression.

statement list — One or more statements.

The ELSEIF and ELSE clauses are optional. The ELSEIF clause contains another test condition that is evaluated only if the preceding condition (expression) is false. The ELSE clause provides a statement list that is executed unconditionally when the preceding expression is false.

When an expression is evaluated as true, the statement list following the reserved word THEN is executed. When the list is completed, execution continues with the first statement following IFEND. If the expression is false, execution continues with the next clause or reserved word in the IF statement format (that is, ELSEIF, ELSE, or IFEND).

If the next reserved word in the IF statement format is IFEND, execution continues with the first statement following it.

If the next reserved word is ELSEIF, the expression contained in that clause is evaluated; if true, the statement list that follows is executed. Otherwise, execution continues with the next reserved word in the IF statement format.

If the next reserved word is ELSE, the statement list that follows is always executed. You get to this point only if the preceding expression(s) is false.

Additional IF statements can be contained (nested) in any of the statement lists. A consistent style of indentation or spacing greatly improves readability of such statements.

If the ELSE clause is included in a nested IF statement, the clause applies to the most recent IF statement.

Examples:

In this example, Y is assigned to X if and only if X is less than Y.

```
IF x < y THEN
  x := y;
IFEND;
```

In this example, Z is always assigned one of the values 1, 2, 3, or 4 depending on the value of X.

```
IF x <= 5 THEN
  z := 1;
ELSEIF x > 30 THEN
  z := 2;
ELSEIF x = 15 THEN
  z := 3;
ELSE
  z := 4;
IFEND;
```

CASE Statement

The CASE statement executes one statement list out of a set of lists based on the value of a given expression.

The format of the CASE statement is:

```
CASE expression OF
 = value {,value}... =
   statement list;
{= value {,value}... =
   statement list;}...
{ELSE statement list;}
CASEND;
```

expression	A scalar expression. The expression must be of the same type as the value or values that follow.
value	One or more constant scalar expressions or a subrange of constant scalar expressions. A subrange indicates that all of the values included in the subrange are acceptable values. If two or more values are specified, they are separated by commas. The values must be of the same type as the expression. Values can be in any order, not strictly sequential. Values must be unique within the CASE statement.
statement list	One or more statements.

You define a set of possible values that a variable or expression can have. With one or more of the values you associate a statement list using the format

```
= value =
  statement list;
```

When the CASE statement is executed, the expression is evaluated and the statement list associated with the current value of the expression is executed. If the current value is not found among those in the CASE statement, execution continues with the ELSE clause. If ELSE is omitted and the value is not found in the CASE statement, an error occurs at execution time. After any one of the statement lists is executed, execution continues with the statement following CASEND.

Examples:

In this example, I is a variable that is expected to take on one of the values 1 through 4. If its value is 1, the first statement list (X := X + 1) is executed and control goes to the statement following CASEND. If the value of I is 2, the second list is executed, and so on.

```
CASE i OF
  = 1 =
    x := x + 1;
  = 2 =
    x := x + 2;
  = 3 =
    x := x + 3;
  = 4 =
    x := x + 4;
CASEND;
```

In this example, OPERATOR is a variable that is expected to take on values of PLUS, MINUS, or TIMES. Depending on the current value of OPERATOR, the associated statement is executed.

```
CASE operator OF
  = plus =
    x := x + y;
  = minus =
    x := x - y;
  = times =
    x := x * y;
CASEND;
```

CYCLE Statement

The CYCLE statement is included in the statement list of a repetitive statement (FOR, REPEAT, or WHILE) and causes any statements following it to be skipped and the next iteration of the repetitive statement to take place.

The format of the CYCLE statement is:

```
CYCLE /label/
```

label — Name that identifies the repetitive statement in which the CYCLE statement is contained.

The CYCLE statement is usually used in conjunction with an IF statement, as in

```
/label/
repetitive statement
    IF expression THEN
    CYCLE /label/;
    IFEND;
    remainder of statement list;
end of repetitive statement;
```

The IF statement tests for a condition which, if true, causes the CYCLE statement to be executed. Then the remaining statements of the repetitive statement are skipped and execution continues with whatever would normally follow the statement list, either another cycle of the repetitive statement or the next statement following the end of the repetitive statement. If the condition in the IF statement is false, the remaining statements in the repetitive statement are executed.

If not contained in a repetitive statement, the CYCLE statement is diagnosed as a compilation error.

Example:

This example finds the smallest element of an array TABLE. On the first execution, X (the first element of the array) is assumed to be smallest. If X is smaller than succeeding elements of the array, the CYCLE statement is executed; the remainder of the statements are then skipped, and the next iteration of the FOR statement occurs. If an element smaller than X is found, the CYCLE statement is ignored and the rest of the statement list is processed; X is replaced by the smaller element. If N has not yet been reached, the FOR statement continues. When N is reached, X will contain the smallest element of the array.

```
x := table[1];

/find_smallest/
 FOR k := 2 TO n DO
   IF x < table[k] THEN
     CYCLE /find_smallest/;
   IFEND;
   x := table[k];
 FOREND /find_smallest/;
```

EXIT Statement

The EXIT statement causes an unconditional exit from a procedure, function, or a structured statement (BEGIN, FOR, REPEAT, and WHILE).

The format of the EXIT statement is:

EXIT name;

name — Name that identifies the procedure, function, or statement. For a procedure or function, it is the procedure or function name. For a structured statement, it is the statement label; in this case the format could be shown as EXIT /label/.

When the EXIT statement is encountered, execution of the named procedure, function, or statement is automatically stopped and execution resumes with the statement that would follow normal completion. For a procedure or function, it is the statement that would normally follow the procedure or function call. For a structured statement, it is the statement following the end of the structured statement (END, FOREND, UNTIL expression, or WHILEND).

The EXIT statement must be within the scope of the procedure, function, or statement it names. Otherwise, it has no meaning and is diagnosed as a programming error.

With a single EXIT statement, you can exit several levels of procedures, functions, or statements; they need not be exited separately. If the EXIT statement is executed in a nested, recursive procedure or function, it is the most recent invocation of the procedure or function and any intervening procedures or functions that are exited.

RETURN Statement

The RETURN statement completes the execution of a procedure or function and returns control to the program, procedure, or function that called it.

The format of the RETURN statement is:

```
RETURN;
```

STORAGE MANAGEMENT STATEMENTS

Storage management statements allow you to manipulate components of sequence and heap types, and put variables in the run-time stack.

There are four storage management statements.

RESET	Resets the pointer in a sequence or releases all the variables in a user-defined heap.
NEXT	Creates or accesses the next element of a sequence given a starting element.
ALLOCATE	Allocates storage for a variable in a heap.
FREE	Releases a variable from a heap.

Sequences use the RESET and NEXT statements. Heaps use the RESET, ALLOCATE, and FREE statements. (Refer to Storage Types in chapter 4 for further information on sequences and heaps.)

In the NEXT and ALLOCATE statements, you must specify a pointer to the variable to be manipulated so that sufficient space can be allocated for that type. This pointer can be a pointer to a fixed type, a pointer to an adaptable type, or a pointer to a bound variant record type. Space is then allocated for a variable of the type to which the pointer can point. This pointer is also used to access the variable. When space is allocated, CYBIL returns the address of the variable to the pointer. Therefore, to reference a variable in a sequence, heap, or the run-time stack, you indicate the object of the pointer in the form, pointer_name ^.

If a fixed type pointer is specified, the statement uses a variable of the type designated by that pointer variable. If an adaptable type pointer or bound variant record type pointer is specified, you must also indicate the size of the adaptable type or the tag field of the variant record to be used. This causes a fixed type to be set and the adaptable or bound variant record pointer designates a variable of that fixed type. That particular fixed type is designated until it is reset by a subsequent assignment or another storage management statement.

To indicate the size of an adaptable pointer or the tag field of a bound variant record pointer, you use the format:

```
pointer : [size]
```

pointer — Name of an adaptable pointer variable or a bound variant record pointer variable.

size — Fixed amount of space required for the variable designated by pointer. You set the size of the adaptable type the same way you specify the size of the corresponding unadaptable (fixed) type. For example, in a variable or type declaration, you specify the size of a fixed array with subscript bounds, usually a subrange of "scalar expression.. scalar expression." You set the size of an adaptable array here using the same form. The forms used to set the size of all possible adaptable types are summarized as follows. For more detailed information, refer to the descriptions of the corresponding fixed types in chapter 4.

Pointer Type	Form Used to Set Size
Adaptable array	scalar expression .. scalar expression
Adaptable string	A positive integer expression specifying the length of the string
Adaptable heap	[{REP positive integer expression OF} fixed type name {,{REP positive integer expression OF} fixed type name}...]
Adaptable sequence	[{REP positive integer expression OF} fixed type name {,{REP positive integer expression OF} fixed type name}...]
Adaptable record	One of the forms used for an adaptable array, string, heap, or sequence.
Bound variant record	A scalar expression or one or more constant scalar expressions followed by an optional scalar expression.

If an adaptable array had a lower bound specified in its original declaration, the lower bound specified here must match that value. For an adaptable record, the form used must be a value and type to which the record can adapt. For a bound variant record, the order, types, and values used must be valid for a variant of the record; all but the last of the expressions must be constant expressions.

Example:

This example declares a type that is an adaptable array named ADAPT_ARRAY. PTR is a pointer to that type. BUNCH is a heap with space for 100 integers. The heap BUNCH is reset; that is, any existing elements are released. Space is then allocated in the heap for a variable of the type designated by PTR. That variable is of type ADAPT_ARRAY (an array of integers) and it has fixed subscript bounds of 1 to 15. PTR now points to that array.

```
TYPE
  adapt_array = array [1..*] of integer;
VAR
  ptr : ^ adapt_array,
  bunch : heap (rep 100 of integer);

RESET bunch;
ALLOCATE ptr : [1..15] IN bunch;
```

RESET Statement

The RESET statement operates on both sequences and heaps. In a sequence, it resets the pointer to the beginning of the sequence or to a specific variable within the sequence. In a heap, it releases all the variables in the heap.

The RESET statement must appear before the first NEXT statement (for a sequence) or ALLOCATE statement (for a user-defined heap). This ensures that the sequence is at the beginning or the heap is empty. If space is allocated before the RESET statement, the program is in error.

RESET in a Sequence

This statement sets the current element being pointed to in a sequence.

The format of the RESET statement in a sequence is:

RESET sequence_pointer { TO variable_pointer }

sequence_pointer	Name of a pointer to a sequence. This specifies the particular sequence.
variable_pointer	Name of a pointer to a particular variable within the sequence. If omitted, the pointer points to the first element of the sequence.

The value of the pointer variable must have been set with a NEXT statement for the same sequence or an error occurs. An error also occurs if the value of the pointer variable is NIL.

The RESET statement must appear before the first occurrence of a NEXT statement to reset the sequence to its beginning; otherwise, the program is in error.

RESET in a Heap

This statement releases the variables currently in a heap.

The format of the RESET statement in a heap is:

    RESET heap

heap	Name of a heap type variable.

Space for the variables is released and their values become undefined.

The RESET statement must appear before the first occurrence of an ALLOCATE statement for a user-defined heap to ensure that the heap is empty; otherwise, the program is in error.

NEXT Statement

The NEXT statement sets the specified pointer to designate the current element of the sequence and then makes the next element in the sequence the current element. This essentially moves the pointer along the sequence allowing you to assign values to and access elements.

The format of the NEXT statement is:

    NEXT pointer { : [size] } IN sequence_pointer

pointer	Name of a pointer to a fixed type, pointer to an adaptable type, or pointer to a bound variant record type. The type being pointed to by the pointer is the type of the variable in the sequence. These pointers are described in more detail in the introduction to this section on storage management statements.
size	Size of an adaptable type or tag field of a bound variant record type. If omitted, the pointer must be a pointer to a fixed type. The forms used to specify size are described in detail in the introduction to this section on storage management statements.
sequence_pointer	Name of a pointer to a sequence. This specifies the particular sequence.

After a RESET statement, the current element is always the first element of the sequence. A NEXT statement assigns to the specified pointer the address of the current (first) element, and then makes the next element (the second) the new current element. Thus, the order of variables in a sequence is determined by the order in which the NEXT statements are executed.

If the NEXT statement causes the new element to be outside the bounds of the sequence, the pointer is set to NIL. Before attempting to reference an element in a sequence, check for a NIL pointer value first. Using a pointer variable with a value of NIL to access an element causes an error to occur.

The type of the pointer specified when data is retrieved from the sequence must be equivalent to the type of the pointer used when the same data was stored in the sequence; otherwise, the program is in error.

ALLOCATE Statement

The ALLOCATE statement allocates storage space for a variable of the specified type in the specified heap and then sets the pointer to point to that variable.

The format of the ALLOCATE statement is:

```
ALLOCATE pointer { : [size] } { IN heap }
```

pointer	Name of a pointer to a fixed type, adaptable type, or bound variant record type. These pointers are described in more detail in the introduction to this section on storage management statements.
size	Size of an adaptable type or tag field of a bound variant record type. If omitted, the pointer must be a pointer to a fixed type. The forms used to specify size are described in detail in the introduction to this section on storage management statements.
heap	Name of a heap type variable. If omitted, the default heap is assumed.

If there is not enough space for the variable to be allocated, the pointer is set to NIL. Before attempting to reference a variable in a heap, check for a NIL pointer value first. Using a pointer variable with a value of NIL to access data causes an error occur.

The RESET statement must appear before the first occurrence of an ALLOCATE statement for a user-defined heap to ensure that the heap is empty; otherwise, the program is in error. (This is not allowed for the default heap.)

The lifetime of a variable that is allocated using the storage management statements is the time between the allocation of storage (with the ALLOCATE statement) and the release of storage (with the FREE statement). A variable allocated using an automatic pointer must be explicitly freed (using the FREE statement) before the block is left or the space will not be released by the program. When the block is left, the pointer no longer exists and, therefore, the variable cannot be referenced. If the block is entered again, the previous pointer and the variable referenced by the pointer cannot be reclaimed.

FREE Statement

The FREE statement releases the specified variable from the specified heap.

The format of the FREE statement is:

```
FREE pointer { IN heap }
```

pointer	Name of the pointer variable that designates the variable to be released.
heap	Name of a heap type variable. If omitted, the default heap is assumed.

The variable's space in the heap is released and its value becomes undefined. The pointer variable designating the released variable is set to NIL. If the specified variable is not currently allocated in the heap, the effect is undefined.

Using a pointer variable with the value NIL to access data causes an error to occur. Releasing the NIL pointer is also an error.

FUNCTIONS 6

A function is one or more statements that perform a specific action and can be called by name from a statement elsewhere in a program. A reference to a function causes actual parameters in the calling statement to be substituted for the formal parameters in the function declaration and then the function's statements to be executed. Usually the function computes a value and returns it to the portion of the program that called it.

A function differs from a procedure in that the value returned for a function replaces the actual function reference within the statement. A function is a valid operand in an expression; the value returned by the function replaces the reference and becomes the operand.

The value of a function is the last value assigned to it before the function returns to the point where it was called. The reason for its return doesn't matter; it could complete normally or abnormally. If the function returns for any reason before a value is assigned to the function name, results are undefined.

Functions can be recursive; that is, a function can call itself. In that case, however, there must be some provision for ending the calls.

You can call functions that are already defined in the language or you can define your own functions. This chapter describes both.

STANDARD FUNCTIONS

The functions described here are standard CYBIL functions. They can be used safely in variations of CYBIL available on other operating systems.

The functions are described in alphabetical order according to the first alphabetic character.

$CHAR FUNCTION

The $CHAR function returns the character whose ordinal number within the ASCII collating sequence is that of a given expression.

The format of the $CHAR function call is:

```
$CHAR(expression)
```

expression	An integer expression whose value can be from 0 through 255.

If the value of the integer expression is less than 0 or greater than 255, an error occurs.

$INTEGER FUNCTION

The $INTEGER function returns the integer value of a given expression.

The format of the $INTEGER function call is:

```
$INTEGER(expression)
```

expression	An expression of type integer, subrange of integer, boolean, character, ordinal, or real.

If the expression is an integer expression, the value of that expression is returned.

If the expression is a boolean expression, 0 (zero) is returned for a false expression and 1 is returned for a true expression.

If the expression is a character expression, the ordinal number of the character in the ASCII collating sequence is returned.

If the expression is an ordinal expression, the ordinal number associated with that ordinal value is returned.

If the expression is a real expression, the value of the expression is truncated to a whole number. If the number is in the range defined for integers, that number is returned; otherwise, an out-of-range error occurs.

#LOC FUNCTION

The #LOC function returns a pointer to the first cell allocated for a given variable.

The format of the #LOC function call is:

```
#LOC(name)
```

name	Name of a variable.

LOWERBOUND FUNCTION

The LOWERBOUND function returns the lower bound of an array's subscript bounds.

The format of the LOWERBOUND function call is:

```
LOWERBOUND(array)
```

array	An array variable or the name of a fixed array type.

The type of the value returned is same as the type of the array's subscript bounds.

Example:

Assuming the following declaration has been made

```
VAR
  x : array [1..100] of boolean,
  y : array ['a'..'t'] of integer;
```

the value of LOWERBOUND(X) is 1; the value of LOWERBOUND(Y) is 'a'.

LOWERVALUE FUNCTION

The LOWERVALUE function returns the smallest possible value that a given variable or type can have.

The format of the LOWERVALUE function call is:

LOWERVALUE(name)

name A scalar variable or name of a scalar type.

The type of the value returned is the same as the given type.

Example:

Assuming the following declaration has been made

```
VAR
  dozen : 1..12;
```

the value of LOWERVALUE(DOZEN) is 1.

PRED FUNCTION

The PRED function returns the predecessor of a given expression.

The format of the PRED function call is:

PRED(expression)

expression A scalar expression.

If the predecessor of the expression does not exist, the program is in error.

$REAL FUNCTION

The $REAL function returns the real number equivalent of a given integer expression.

The format of the $REAL function call is:

    $REAL(expression)

        expression   An integer expression.

#SIZE FUNCTION

The #SIZE function returns the number of cells required to contain a given variable or a variable of a specified type.

The format of the #SIZE function call is:

    #SIZE(name)

        name   Name of a variable, fixed record type, or bound variant record type.

If the name of a bound variant record type is specified, the variant that requires the largest size is used.

STRLENGTH FUNCTION

The STRLENGTH function returns the length of a given string.

The format of the STRLENGTH function call is:

    STRLENGTH(string)

        string   A string variable, name of a string type, or adaptable string reference.

For a fixed string, the allocated length is returned as an integer subrange. For an adaptable string, the current length is returned.

SUCC FUNCTION

The SUCC function returns the successor of a given expression.

The format of the SUCC function call is:

    SUCC(expression)

        expression   A scalar expression.

If the successor of the expression does not exist, the program is in error.

UPPERBOUND FUNCTION

The UPPERBOUND function returns the upper bound of an array's subscript bounds.

The format of the UPPERBOUND function call is:

    UPPERBOUND(array)

        array   An array variable or the name of a fixed array type.

The type of the value returned is the same as the type of the array´s subscript bounds.

Example:

Assuming the following declaration has been made

```
VAR
  x : array [1..100] of boolean,
  y : array ['a'..'t'] of integer;
```

the value of UPPERBOUND(X) is 100; the value of UPPERBOUND(Y) is ´t´.

UPPERVALUE FUNCTION

The UPPERVALUE function returns the largest possible value that a given variable or type can have.

The format of the UPPERVALUE function call is:

    UPPERVALUE(name)

        name   A scalar variable or name of a scalar type.

The type of the value returned is the same as the given type.

Example:

Assuming the following declaration has been made

```
VAR
  dozen : 1..12;
```

the value of UPPERVALUE(DOZEN) is 12.

USER-DEFINED FUNCTIONS

You define your own functions with function declarations.

FUNCTION DECLARATION

The format used for specifying a function is:

```
FUNCTION {[attributes]} name {ALIAS 'alias_name'}†{(formal_parameters)} : result_type;
    {declaration_list}
    statement_list
FUNCEND {name} ;
```

attributes†† — One or more of the following attributes. If more than one are specified, they are separated by commas.

Attribute	Meaning
XREF	The function has been compiled in a different module. In this case, the function declaration can contain the name and formal parameters, but no declaration list or statement list. In the other module, the function must have been declared with the XDCL attribute and an identical parameter list. If omitted, the function must be defined within the module where it is referenced.
XDCL	The function can be referenced from outside of the module in which it is located. This attribute can be included only in a function declared at the outmost level of a module; it cannot be contained in a program, procedure, or another function. Other modules that reference this function must contain the same function declaration with the XREF attribute specified.

If no attributes are specified, the function is assumed to be in the same module in which it is called.

†CYBIL P-Code accepts an alias name, but it is ignored.

††Some variations of CYBIL available on other operating systems allow an additional attribute, the #GATE attribute. CYBIL P-Code accepts the #GATE attribute, but it is ignored.

name	Name of the function. The function name is optional following FUNCEND.
alias_name	An alternate name for the function which can be used outside of the compilation unit in which it is defined. The name must be enclosed in apostrophes. When the alias_name is included in a function declaration, the XDCL attribute must also be specified. The keyword ALIAS and the alias_name are optional.
formal_parameters	One or more parameters in the form

```
    VAR name {,name}... : type
        {,name {,name}... : type}...
```

and/or

```
    name {,name}... : type
        {,name {,name}... : type}...
```

The first form is called a reference parameter; the second form is called a value parameter. There is essentially no difference between them in the context of a function. However, procedures (and programs) do treat them differently. Both kinds of parameters can appear in the formal parameter list; if so, they are separated by semicolons (for example, I:INTEGER; VAR A:CHAR). Reference and value parameters are discussed in more detail later in this chapter under Parameter Lists.

result_type	The type of the result to be returned. It can be any scalar, floating-point, pointer, or cell type.
declaration_list	Zero or more declarations.
statement_list	One or more statements.

In an assignment statement within a function, the lefthand side of the statement (the variable to receive the value) cannot be:

- A nonlocal variable.
- A formal parameter of the function.
- The object of a pointer variable.

User-defined functions cannot contain:

- Procedure call statements that call user-defined procedures.
- Parameters of type pointer to procedure.
- ALLOCATE, FREE, or NEXT statements that have parameters that are not local variables.

PARAMETER LIST

A parameter list is an optional list of variable declarations that appears in the first statement of the function declaration. In the function declaration format shown earlier, they are shown as "formal_parameters." Declarations for formal parameters must appear in that first statement; they cannot appear in the declaration list in the body of the function.

A parameter list allows you to pass values from the calling program to the function. When a call is made to a function, parameters called actual parameters are included with the function name. The values of those actual parameters replace the formal parameters in the parameter list. Wherever the formal parameters exist in the statements within the function, the values of the corresponding actual parameters are substituted. For every formal parameter in a function declaration, there must be a corresponding actual parameter in the function call.

There are two kinds of parameters: reference parameters and value parameters. A reference parameter has the form

```
VAR name {,name}... : type
    {,name {,name}... : type}...
```

A value parameter has the form

```
name {,name}... : type
    {,name {,name}... : type}...
```

Procedures make a distinction between the two types of parameters but functions do not. (In a procedure, the value of a reference parameter can change during execution of the procedure; a value parameter cannot change.) In a function, neither reference parameters nor value parameters can change in value. A formal reference parameter can be any fixed or adaptable type. A formal value parameter can be any fixed or adaptable type, except a heap or an array or record that contains a heap.

Reference parameters and value parameters can be specified in many combinations. When both kinds of parameters appear together, they must be separated by semicolons. Parameters of the same type can also be separated by semicolons instead of commas but, in this case, VAR must appear with each reference parameter. All of the following parameter lists are valid.

```
VAR i, j : integer; a, b : char;

VAR i : integer; VAR j : integer; a : char; b : char;

a : char; VAR i, j : integer; b : char;

VAR i : integer, j : real; a : char, b : boolean;
```

In each of the preceding examples, I and J are reference parameters; A and B are value parameters.

REFERENCING A FUNCTION

The call to the function is usually contained in an expression. The call consists of the function name (as given in the function declaration) and any parameters to be passed to the function in the following format:

```
name ({actual_parameters})
```

name	Name of the function.
actual_parameters	Zero or more expressions or variables to be substituted for formal parameters defined in the function declaration. If two or more are specified, they are separated by commas. They are substituted one-for-one based on their position within the list; that is, the first actual parameter replaces the first formal parameter, the second actual parameter replaces the second formal parameter, and so on. For every formal parameter in a function declaration, there must be a corresponding actual parameter in the function call. If there were no formal parameters specified in the function declaration, there can be no actual parameters included in the function call. However, left and right parentheses are required to indicate the absence of parameters. In this case, the call is name( )

The function can be anywhere that a variable of the same type could be. The value returned by a function is the last value assigned to it. If control is returned to the calling point before an assignment is made, results are undefined.

The only types that can be returned as values of functions are the basic types: scalar, floating point, pointer, and cell.

Example:

This function finds the smaller of two integer values represented by formal value parameters A and B. The smaller value is assigned to MIN, the name of the function, and that integer value is returned.

```
FUNCTION min (a, b : integer) : integer;
  IF a > b THEN
    min := b;
  ELSE
    min := a;
  IFEND;
FUNCEND min;
```

The preceding function could be called using the following reference.

```
smaller := min(first,second);
```

The value of the variable FIRST is substituted for the formal parameter A; the value of SECOND is substituted for B. The value returned, the smaller value, replaces the entire function reference; the variable SMALLER is assigned the smaller value.

PROCEDURES 7

A procedure is one or more statements that perform a specific action and can be called by a single statement. A procedure allows you to associate a name with the statement list so that by specifying the name itself as if it were a statement, you cause the list to be executed. Declarations can be included and take effect when the procedure is called. A procedure call can optionally cause actual parameters included in the call to be substituted for the formal parameters in the procedure declaration before the procedure's statements are executed.

A procedure differs from a function in that

- A procedure can, but does not always, return a value.
- The call to a procedure is the procedure's name itself; a function call by contrast must be part of an expression in a statement.
- There can be no value assigned to the procedure name as there is to a function name.

You can call procedures that are already defined in the language or you can define your own procedures. This chapter describes both.

STANDARD PROCEDURES

The STRINGREP procedure described here is a standard CYBIL procedure. It can be used safely in variations of CYBIL available on other operating systems.

STRINGREP PROCEDURE

The STRINGREP procedure converts one or more elements to a string of characters, then returns that string and the length of the string.

The format of the STRINGREP procedure call is:

```
STRINGREP(string_name, length, element {,element}...)
```

string_name	Name of a string type variable. The result is returned here. It will contain the character representations of the named element(s).
length	Name of an integer variable. Its value will be the length in characters of the resulting string variable, string_name. It will be less than or equal to the declared length of the string variable.
element	Name of the element to be converted. The element can be a scalar, floating-point, pointer, or string type. Formats for specifying particular types and rules for conversion of those types are discussed in more detail later in this chapter.

The named elements are converted to strings of characters. Those strings are then concatenated and returned left-justified in the named string variable. The length of the string variable is also returned. If the result of concatenating the string representations is longer than the length of the string variable, the result is truncated on the right; the length that will be returned is the length of the string variable.

Each individual element is converted and placed in a temporary field before concatenation with other elements. The length of the temporary field can be specified as part of the element parameter that is described in the following sections. Generally, numeric values are written right-justified in the temporary field with blanks on the left filling the field if necessary. String or character values are written left-justified in the temporary field with blanks on the right filling the field if necessary. For both numeric and alphabetic values, the field is filled with asterisk characters if it is too short to hold the resulting value. The value of the field length, when specified, must be greater than or equal to zero; otherwise, an error occurs.

The following paragraphs describe how the STRINGREP procedure converts specific types and how they appear in the temporary fields.

Integer Element

The format for specifying an integer element is:

```
expression { : length } { : #(radix) }
```

expression	An integer expression to be converted.
length	A positive integer expression specifying the length of the temporary field. The length must be greater than or equal to 2. If omitted, the temporary field is the minimum size required to hold the integer value and the leading sign character.
radix	Radix of expression. Possible values are 2, 8, 10, and 16. If omitted, 10 (decimal) is assumed.

The value of the integer expression is converted into a string representation in the desired radix. The resulting string representation is right-justified in the temporary field. If the expression is positive, a blank character precedes the leftmost significant digit. If the integer expression is negative, a minus sign precedes the leftmost significant digit. The leading blank or hyphen must be considered a part of the length. (Thus, the length must be greater than or equal to 2 in order to hold the sign character and at least one digit.)

If a field length larger than necessary is specified, blanks are added on the left to fill the field. If the field length is not long enough to contain all digits and the sign character, the field is filled with a string of asterisk characters. If the field length is less than or equal to zero, an error occurs.

Character Element

The format for specifying a character element is:

    expression { : length }

expression	A character expression to be converted.
length	A positive integer expression specifying the length of the temporary field. If omitted, a length of 1 is assumed.

A single character is left-justified in the temporary field. If a field length larger than necessary is specified, blanks are appended to the right to fill the field. Including a radix for a character element causes a compilation error.

Boolean Element

The format for specifying a boolean element is:

    expression { : length }

expression	A boolean expression to be converted.
length	A positive integer expression specifying the length of the temporary field. If omitted, a length of 5 is assumed.

Either of the five-character strings ' TRUE' or 'FALSE' is left-justified in the temporary field. If a field length larger than necessary is specified, blanks are appended on the right to fill the field. If the field length is not long enough to contain all five characters, the temporary field is filled with asterisk characters. Including a radix for a boolean element causes a compilation error to occur.

Ordinal Element

The integer value of an ordinal expression is handled the same way as an integer element. Refer to the discussion of Integer Element earlier in this chapter.

Subrange Element

A subrange element is handled the same way as the element of which it is a subrange.

Floating-Point Element

The format for specifying a floating-point element is:

```
expression { : length { : fraction } }
```

expression	A real expression to be converted. If the value is INFINITE or INDEFINITE, an error occurs.
length	A positive integer expression specifying the length of the temporary field. If omitted, the temporary field is the minimum size required to hold the integer value and the necessary leading character.
fraction	Positive integer expression specifying number of fractional digits to be included in a fixed point format. Its value must be less than or equal to "length - 2." If omitted, conversion to floating-point format is assumed.

A floating-point expression can be converted into either a fixed-point format or a floating-point format depending on the fraction parameter. If it is included, the expression is converted to fixed-point format; if omitted, the expression is converted to floating-point format.

Fixed-Point Format

The form

```
expression : length : fraction
```

causes the specified expression to be converted to a string in fixed-point format. The string will have the specified length with the specified number of fractional digits to the right of the decimal place. The expression is rounded off so that the specified number of fractional digits are present. If no positive digit appears to the left of the decimal point, a zero is inserted. When figuring the length required to hold the expression, the compiler counts all digits to the left of the decimal point (including 0 if it appears alone), the decimal point, and the specified number of fractional digits that appear to the right of the decimal point. If the expression is negative, an extra space is required for the minus sign. If a field length larger than necessary is specified, blanks are added the left to fill the field. If the field length specified is not long enough to contain all digits, the sign character, and the decimal point, the field is filled with a string of asterisk characters.

Examples:

Value of Expression E	Format of Element	Resulting String
1.23456	E:6:2	' 1.23'
-1.23456	E:6:3	'-1.235'
0	E:5:2	' 0.00'

Floating-Point Format

The form

    expression : length

causes the specified expression to be converted to a string in floating-point format.

The length of the temporary field is determined somewhat differently from the other elements. The system defines a maximum number of digits that can be contained in the mantissa of a real number and the number of digits that can be in the exponent. When the compiler figures the number of digits that will be in the mantissa, it first determines the number of spaces that must be present in the string. The number of digits in the exponent is required as are four additional spaces: one for the sign of the expression (a blank if positive, - if negative), one for the decimal point in the mantissa, one for the exponent character (E), and one for the sign of the exponent (+ or -). The total number of required spaces is subtracted from the specified field length. The compiler then compares the result (field length minus required spaces) and the maximum number of digits allowed in the mantissa, and takes the smaller of the two. That number is used for the number of digits to be in the mantissa when the compiler rounds the floating-point expression.

If a field length larger than necessary is specified, blanks are added on the left to fill the field. If the fixed size of the exponent is larger than necessary, zeroes are filled in on the left. If the number that results from the subtraction of required spaces from the field length is less than 1, the field is filled with a string of asterisk characters.

Examples:

Value of Expression E	Format of Element	Resulting String
123.456	E:10	' 1.23E+002'
-123.456	E:11	'-1.235E+002'

Pointer Element

The format for specifying a pointer element is:

    pointer { : length } { : #(radix) }

pointer
: A pointer reference to be converted.

length
: A positive integer expression specifying the length of the temporary field. If the field length is omitted, the temporary field is the minimum size required to contain the pointer value.

radix
: Radix of the pointer value. Possible values are 2, 8, 10, and 16. For CYBIL P-CODE, the default radix is 16.

The value of a pointer expression is converted into a string representation in the specified radix. It is right-justified in the temporary field. If a field length larger than necessary is specified, blanks are added on the left to fill the field. If the field length is not long enough to contain all the digits, the field is filled with a string of asterisk characters.

String Element

The format for specifying a string element is:

```
expression { : length }
```

expression	A string variable, string constant, or substring to be converted.
length	A positive integer expression specifying the length of the temporary field. If omitted, the field is the minimum size required to contain the string expression.

A string expression is left-justified in the temporary field. If a field length larger than necessary is specified, blanks are appended to the right to fill the field. If the field length is shorter than the length of the string, the temporary field is filled with a string of asterisk characters.

USER-DEFINED PROCEDURES

You define your own procedures with procedure declarations.

PROCEDURE DECLARATION

The format used for specifying a procedure is:

```
PROCEDURE {[attributes]} name {ALIAS 'alias_name'}† {(formal_parameters)};
    {declaration_list}
    {statement_list}
PROCEND {name}
```

attributes†† — One or more of the following attributes. If more than one are specified, they are separated by commas.

Attribute	Meaning
XREF	The procedure has been compiled in a different module. In this case, the procedure declaration can contain the name and formal parameters, but no declaration list or statement list. In the other module, the procedure must have been declared with the XDCL attribute and an identical parameter list. If omitted, the procedure must be defined within the module where it is called.
XDCL	The procedure can be called from outside of the module in which it is located. This attribute can be included only in a procedure declared at the outmost level of a module; it cannot be contained in a program, function, or another procedure. Other modules that call this procedure must contain the same procedure declaration with the XREF attribute specified.

†CYBIL P-Code accepts an alias name, but it is ignored.

††Some variations of CYBIL available on other operating systems allow an additional attribute, the #GATE attribute. CYBIL P-Code accepts the #GATE attribute, but it is ignored.

Attribute	Meaning
INLINE	Instead of calling the procedure, the compiler inserts the actual procedure statements at the point in the code where the procedure call is made. If no attributes are specified, the procedure is assumed to be in the same module in which it is called.

name — Name of the procedure. The procedure name is optional following PROCEND.

alias_name — An alternate name for the procedure which can be used outside of the compilation unit in which it is defined. The name must be enclosed in apostrophes. When the alias_ name is included in a procedure declaration, the XDCL attribute must also be specified. The keyword ALIAS and alias_name are optional.

formal_parameters — One or more parameters in the form

```
VAR name {,name}... : type
    {,name {,name}... : type}...
```

and/or

```
name {,name}... : type
     {,name {,name}... : type}...
```

The first form is called a reference parameter; its value can be changed during execution of the procedure. The second form is called a value parameter; its value cannot be changed by the procedure. Both kinds of parameters can appear in the formal parameter list; if so, they are separated by semicolons (for example, I:INTEGER; VAR A:CHAR). Reference and value parameters are discussed in more detail later in this chapter under Parameter Lists.

declaration_list — Zero or more declarations.

statement_list — Zero or more statements.

PARAMETER LIST

A parameter list is an optional list of variable declarations that appears in the first statement of the procedure declaration. In the procedure declaration format shown earlier, they are shown as "formal_parameters." Declarations for formal parameters must appear in that first statement; they cannot appear in the declaration list in the body of the procedure.

A parameter list allows you to pass values from the calling program to the procedure. When a call is made to a procedure, parameters called actual parameters are included with the procedure name. The values of those actual parameters replace the formal parameters in the parameter list. Wherever the formal parameters exist in the statements within the procedure, the values of the corresponding actual parameters are substituted. For every formal parameter in a procedure declaration, there must be a corresponding actual parameter in the procedure call.

There are two kinds of parameters: reference parameters and value parameters. A reference parameter has the form

```
VAR name {,name}... : type
    {,name {,name}... : type}...
```

When a reference parameter is used, the formal parameter represents the corresponding actual parameter throughout execution of the procedure. Thus, an assignment to a formal parameter changes the variable that was passed as the corresponding actual parameter. An actual parameter corresponding to a formal reference parameter must be addressable. A formal reference parameter can be any fixed or adaptable type. If the formal parameter is a fixed type, the actual parameter must be a variable or substring of an equivalent type. If the formal parameter is adaptable, the actual parameter must be a variable or substring whose type is potentially equivalent. (For further information on potentially equivalent types, refer to Equivalent Types in chapter 4.)

A value parameter has the form

```
name {,name}... : type
    {,name {,name}... : type}...
```

When a value parameter is used, the formal parameter takes on the value of the corresponding actual parameter. However, the procedure cannot change a value parameter by assigning a value to it or using it as an actual reference parameter to another procedure or function. A formal value parameter can be any fixed or adaptable type except a type that cannot have a value assigned, that is, a heap, or an array or record that contains a heap. If the formal parameter is a fixed type, the actual parameter can be any expression that could be assigned to a variable of that type. Strings must be of equal length. If the formal parameter is an adaptable type, the current type of the actual parameter must be one to which the formal parameter can adapt. If the formal parameter is an adaptable pointer, the actual parameter can be any pointer expression that could be assigned to the formal parameter. Both the value and the current type of the actual parameter are assigned to the formal parameter.

Reference parameters and value parameters can be specified in many combinations. When both kinds of parameters appear together, they must be separated by semicolons. Parameters of the same type can also be separated by semicolons instead of commas but, in this case, VAR must appear with each reference parameter. All of the following parameter lists are valid.

```
VAR i, j : integer; a, b : char;

VAR i : integer; VAR j : integer; a : char; b : char;

a : char; VAR i, j : integer; b : char;

VAR i : integer, j : real; a : char, b : boolean;
```

In each of the preceding examples, I and J are reference parameters; A and B are value parameters.

CALLING A PROCEDURE

A call to a procedure consists of the procedure name (as given in the procedure declaration) and any parameters to be passed to the procedure in the following format:

```
name {(actual_parameters)} ;
```

name	Name of the procedure or a pointer to a procedure.
actual_parameters	One or more expressions or variables to be substituted for formal parameters defined in the procedure declaration. If two or more are specified, they are separated by commas. They are substituted one-for-one based on their position within the list; that is, the first actual parameter replaces the first formal parameter, the second actual parameter replaces the second formal parameter, and so on. For every formal parameter in a procedure declaration, there must be a corresponding actual parameter in the procedure call.

A procedure is a type, like the types described in chapter 3. Procedure types are used for declaration of pointers to procedures; there are no procedure variables.

The lifetime of a formal parameter is the lifetime of the procedure in which it is a part. Storage space for the parameter is allocated when the procedure is entered and released when the procedure is left.

The lifetime of a variable that is allocated using the storage management statements (described in chapter 5) is the time between the allocation of storage (with the ALLOCATE statement) and the release of storage (with the FREE statement).

Two procedure types are equivalent if corresponding parameter segments have the same number of formal parameters, the same methods of passing parameters (reference or value), and equivalent types.

Example:

This example calculates the greatest common divisor X of M and N. M and N are passed as value parameters; that is, their values are used but M and N themselves are not changed. X, Y, and Z are reference parameters (preceded by the VAR keyword). Their original values have no meaning in the procedure; they are assigned new values in the procedure that destroy their previous values.

```
PROCEDURE gcd (m,n : integer; VAR x, y, z : integer);

  VAR a1, a2, b1, b2, c, d, q, r : integer;

  a1 := 0;
  a2 := 1;
  b1 := 1;
  b2 := 0;
  c := m;
  d := n;

  WHILE d <> 0 DO
    q := c DIV d;
    r := c MOD d;
    a2 := a2 - q * a1;
    b2 := b2 - q * b1;
    c := d;
    d := r;
    r := a1;
    a1 := a2;
    a2 := r;
    r := b1;
    b1 := b2;
    b2 := r;
  WHILEND;

  x := c;
  y := a2;
  z := b2;
PROCEND gcd;
```

THE CYBIL COMMAND AND OTHER COMPILATION FACILITIES

This chapter describes the CYBIL command and the declarations, statements, and directives that can be used at compilation time. The CYBIL command is used to compile one or more CYBIL modules. The compilation statements and directives are used to construct the unit to be compiled and control that process. If a compiler command and a directive specify conflicting options, the option encountered most recently is used.

CYBIL COMMAND

The CYBIL command calls the compiler, specifies the files to be used for input and output, and indicates the type of output to be produced.

Instructions for calling the compiler are given in the SES User's Handbook listed in the perface.

COMPILATION DECLARATIONS AND STATEMENTS

Many program elements defined in CYBIL have counterparts that can be used to control the compilation process. They include variable declarations, expressions, and the assignment and IF statements. The IF statement is used to specify certain areas of code to be compiled. The IF statement requires the use of expressions, which in turn require variables. Assignment statements are used to change the value of variables and thus, expressions.

COMPILE TIME VARIABLES

Only boolean type variables can be declared.

The format used to specify a boolean type compile time variable is:

```
? VAR name {,name}... : BOOLEAN := expression
      {, name {,name}... : BOOLEAN := expression}... ?;
```

name	Name of the compile time variable. This name must be unique among all other names in the program.
expression	A compile time expression that specifies the initial value of the variable.

A compile time declaration must appear before any compile time variables are used. The scope of such a variable extends from the point at which it is declared to the end of the module. Compile time variables can be used only in compile time expressions and compile time assignment statements.

COMPILE TIME EXPRESSIONS

Compile time expressions are composed of operands and operators like CYBIL-defined expressions. An operand can be

- Either of the constants TRUE or FALSE.
- A compile time variable.
- Another compile time expression.

The operators are NOT, AND, OR, and XOR. Their order of evaluation from highest to lowest is

- NOT
- AND
- OR and XOR

These operators have their normal meanings, as described under Operators in chapter 5.

COMPILE TIME ASSIGNMENT STATEMENT

A compile time assignment statement assigns a value to a compile time variable.

The format of the compile time assignment statement is:

```
? name := expression ?;
```

name	Name of a compile time variable.
expression	A compile time expression.

COMPILE TIME IF STATEMENT

The compile time IF statement compiles or skips a certain area of code depending on whether a given expression is true of false.

The format of the compile time IF statement is:

```
? IF expression THEN
    code
  { ? ELSE
    code }
? IFEND
```

expression	A boolean compile time expression.
code	An area of CYBIL code or text.

When the expression is evaluated as true, the code following the reserved word THEN is compiled. When compilation of that code is completed, compilation continues with the first statement following IFEND. When the expression is false, compilation continues following the ELSE phrase, if it is included, or IFEND.

The ELSE clause is optional. If included, the ELSE clause designates an area of code that is compiled when the preceding expression is false.

Example:

This example shows the declaration of a compile time variable named SMALL_SIZE that is initialized to the value TRUE. A line of CYBIL code declaring an array named TABLE is compiled. Then a compile time IF statement checks the value of SMALL_SIZE. If it is TRUE, the line of CYBIL code calling a procedure named BUBBLESORT is compiled in the program. If it is FALSE, the CYBIL line calling procedure QUICKSORT is inserted instead. Because SMALL_SIZE was initialized to TRUE, the call to BUBBLESORT is included in the compiled program.

```
? VAR small_size : boolean := TRUE ?;

VAR table : array [1..50] of integer;

? IF small_size = TRUE THEN

  bubblesort (table);

? ELSE

  quicksort (table);

? IFEND
```

COMPILE TIME DIRECTIVES

Compile time directives allow you to perform the following activities during compilation.

- Set toggles that turn on or off listing options such as source code listing and object code listing (SET, PUSH, POP, and RESET directives when they contain one or more of the listing options).
- Set toggles that turn on or off run time options such as range checking and array subscript checking (SET, PUSH, POP, and RESET directives when they contain one or more of the run time checking options).
- Specify the layout of the source text to be used (LEFT and RIGHT margin directives).
- Specify the layout of the resulting listing (EJECT, SPACING, SKIP, NEWTITLE, TITLE, and OLDTITLE directives).
- Specify what code to compile (COMPILE and NOCOMPILE directives).
- Include comments in the object module (COMMENT directive).

You can specify one or more directives with the format:

```
?? directive {,directive}... ??
```

directive — One of the directives discussed in the remainder of this chapter. They can be broken down into four categories:

- Toggle control (SET, PUSH, POP, and RESET)
- Layout control (LEFT, RIGHT, EJECT, SPACING, SKIP, NEWTITLE, TITLE, and OLDTITLE)
- Maintenance control (COMPILE and NOCOMPILE)
- Object code comment control (COMMENT)

Directives must be bounded by a pair of consecutive question marks. These delimiters are not shown in the following formats for individual directives, but they are required around one or more directives.

If a directive differs from an option specified on a compiler command, the latest occurrence of either the directive or the command takes precedence.

TOGGLE CONTROL

Toggle controls can set the values of individual toggles; save and restore preceding toggle values in a last in/first out manner; and reset all toggles to their initial values.

SET Directive

The SET directive specifies the setting of one or more toggles.

The format of the SET directive is:

```
SET (toggle_name := condition {,toggle_name := condition}...)
```

toggle_name — Name of the toggle being set. Listing toggles are described in table 8-1. Run time checking toggles are described in table 8-2. The names of toggles can be used freely outside of directives.

condition — ON or OFF. If a toggle is ON, the activity associated with it is performed during compilation; if it is OFF, the activity is not performed.

All settings specified in the SET directive are performed together. If the directive list contains more than one setting for a single toggle, the rightmost setting in the list is used.

Table 8-1 describes the listing toggles and gives their initial settings.

Table 8-1. Listing Toggles

Toggle	Initial Value	Description
LIST	ON	Determines whether other listing toggles are read. When ON, a source listing is produced and the other listing toggles are used to control other aspects of listing. When OFF, no listing is produced; the other listing toggles are ignored.
LISTOBJ	OFF	Controls the listing of generated object code. When ON, object code is interspersed with source code following the corresponding source code line.
LISTCTS	OFF	Controls the listing of the listing toggle directives and layout directives.
LISTEXT	OFF	When ON, the listing of source statements is controlled by a list option on the CYBIL compiler command.
LISTALL	Not applicable	This option represents all of the listing toggles. When ON, all other listing toggles are ON; when OFF, all other listing toggles are OFF.

Table 8-2 describes the run time checking toggles and gives their initial settings.

Table 8-2. Run Time Checking Toggles

Toggle	Initial Value	Description
CHKRNG	ON	Controls the generation of object code that performs range checking of scalar subrange assignments and case variables.
CHKSUB	ON	Controls the generation of object code that checks array subscripts (indexes) and substring selections to verify that they are valid.
CHKNIL	OFF	Controls the generation of object code that checks for a NIL value when a reference is made to the object of a pointer.
CHKALL	Not applicable	This option represents all run time checking toggles. When ON, all other run time checking toggles are ON; when OFF, all other run time checking toggles are OFF.

PUSH Directive

The PUSH directive specifies the setting of one or more toggles like the SET directive but, before the settings are put into effect, a record of the current state of all toggles is saved for later use.

The format of the PUSH directive is:

```
PUSH (toggle_name := condition {,toggle_name := condition}...)
```

toggle_name	Name of the toggle being set. Listing toggles are described in table 8-1. Run time checking toggles are described in table 8-2. The names of toggles can be used freely outside of directives.
condition	ON or OFF. If a toggle is ON, the activity associated with it is performed during compilation; if it is OFF, the activity is not performed.

Settings in the PUSH list are performed in the same manner as a SET list. If the directive list contains more than one setting for a single toggle, the rightmost setting in the list is used.

The POP directive, described later in this chapter, restores the original toggle settings in a last in/first out manner (that is, the last record to be saved is the first to be restored).

POP Directive

The POP directive restores the last toggle settings that were saved by the PUSH directive.

The format of the POP directive is:

```
POP
```

If no record was kept (such as the case when a SET directive is performed), the initial settings are restored.

RESET Directive

The RESET directive restores the initial toggle settings.

The format of the RESET directive is:

```
RESET
```

When the RESET directive is performed, any record of previous settings is destroyed.

LAYOUT CONTROL

Layout controls are used to specify the margins of the source text and to control the layout of the listing.

LEFT and RIGHT Directives

The LEFT and RIGHT directives specify the column number of the left and right margins of the source text, respectively.

The formats of the LEFT and RIGHT directives are:

LEFT := integer

RIGHT := integer

integer — An integer value that represents the column number of the left and right margins respectively.

The left margin must be greater than zero; that is,

left margin > 0

The right margin must be greater than or equal to the left margin plus 10, and less than or equal to 110; that is,

left margin + 10 <= right margin <= 110

All source text left of the left margin and right of the right margin is ignored.

If the margin directives are not used, the left margin is assumed to begin in column 1 and the right margin in column 79.

Example:

This example sets the left margin at column 1 and the right margin at column 110.

```
?? LEFT := 1, RIGHT := 110 ??
```

EJECT Directive

The EJECT directive causes the paper to be advanced to the top of the next page.

The format for specifying the EJECT directive is:

EJECT

SPACING Directive

The SPACING directive specifies the number of blank lines between individual lines of the listing.

The format of the SPACING directive is:

SPACING := spacing

spacing — One of the values 1, 2, or 3 specifying single, double, and triple spacing, respectively.

An undefined value has no effect on spacing, but an error message is issued.

If the SPACING directive is not used, single spacing (no intervening blank lines) is assumed.

SKIP Directive

The SKIP directive specifies that a given number of lines is to be skipped.

The format of the SKIP directive is:

```
SKIP := lines
```

lines — Integer value specifying the number of lines to skip. It must be greater than or equal to 1.

If the number of lines specified is larger than the number of lines on the page, or if it would cause the paper to skip past the bottom of the current page, the paper is advanced to the top of the next page.

NEWTITLE Directive

The NEWTITLE directive specifies a new, additional title to be used on a page while saving the current title.

The format of the NEWTITLE directive is:

```
NEWTITLE := 'character_string'
```

character_string — A character string specifying the title to be used. A single quote mark is indicated by two consecutive quote marks enclosed by quote marks (that is, '''').

The current title is saved and the given character string becomes the current title. A standard page header is always the first title printed on a page, followed by user-defined titles in the order in which they were saved. This means that titles are saved and restored in a last in/first out order, but they are printed in a first in/first out order. There is always a single empty line between the standard page header and any user-defined titles. There is always at least one empty line between the last title and the text.

The maximum number of titles that can be specified is 10. Any attempts to add more titles is ignored.

Titling does not take effect until the top of the next printed page.

TITLE Directive

The TITLE directive replaces the current user-defined title with the given character string.

The format of the TITLE directive is:

```
TITLE := 'character_string'
```

character_string — A character string specifying the title to be used. A single quote mark is indicated by two consecutive quote marks enclosed by quote marks (that is, '''').

If there is no user-defined title currently, the character string becomes the current title.

A standard page header is always the first title printed on a page. There is always a single empty line between the standard page header and any user-defined titles. There is always at least one empty line between the last title and the text.

Titling does not take effect until the top of the next printed page.

OLDTITLE Directive

The OLDTITLE directive restores the last user-defined title that was saved, making it the current title.

The format of the OLDTITLE directive is:

```
OLDTITLE
```

If there is no saved title, no action occurs.

MAINTENANCE CONTROL

Maintenance controls specify when compilation should occur.

COMPILE Directive

The COMPILE directive causes compilation to occur, or to resume after the occurrence of a NOCOMPILE directive.

The format of the COMPILE directive is:

```
COMPILE
```

If neither the COMPILE nor NOCOMPILE directive is used, the COMPILE directive is assumed; source code is compiled.

NOCOMPILE Directive

The NOCOMPILE directive causes compilation to stop until the occurrence of a COMPILE directive or the end of the module.

The format of the NOCOMPILE directive is:

    NOCOMPILE

NOCOMPILE continues listing source code and text according to the listing toggles and layout directives, interpreting and obeying directives, but source code is not compiled until a COMPILE directive is encountered or a MODEND statement is encountered.

COMMENT CONTROL

Comment control allows you to put documentation in object code using the COMMENT directive.

COMMENT Directive

The COMMENT directive causes the compiler to include the given character string in the commentary portion of the object module generated by the compilation process.

The format of the COMMENT directive is:

    COMMENT := 'character_string'

character_string	A character string up to 40 characters that specifies a compile time comment.

This directive allows you to include comments in object modules so that the comments appear in the load maps. Any number of comments can be included but only the last comment encountered appears.

Example:

```
?? COMMENT := 'Copyright Control Data Corporation 1984' ??
```

GLOSSARY A

Access Attribute

A characteristic of a variable that determines whether the variable can be both read and written. Specifying the access attribute READ makes the variable a read-only variable.

Alphabetic Character

One of the following letters.

A to Z

a to z

See Alphanumeric Character and Character.

Alphanumeric Character

An alphabetic character or a digit. See Alphabetic Character, Character, and Digit.

Boolean

Type of value. The boolean values are the boolean (logical) constants TRUE and FALSE.

Boolean Expression

An expression that, when evaluated, results in a boolean value.

Byte

A group of bits. For CYBIL P-Code, a byte is 8 bits. An ASCII character code uses one byte.

Byte Offset

A number corresponding to the number of bytes beyond the beginning of a line, procedure, module, or section.

Character

A graphic character or control character that is represented by a code in a character set. A graphic character is printable; a control character is nonprintable and is used to control an input or output operation. Also, a byte when used as a unit of block length, record length, and so forth. See Alphabetic Character and Alphanumeric Character.

Character Constant

A fixed value that represents a character.

Comment

Any character or sequence of characters that is preceded by a left brace and terminated by a right brace or an end of line. A comment is treated exactly as a space.

Delimiter

An indicator that separates and organizes data.

Digit

One of the following characters:

0 1 2 3 4 5 6 7 8 9

See Hexadecimal Digit.

Entry Point

Point within a module at which execution of the module begins when called by another module.

Expression

A notation that represents a value. A constant or variable appearing alone, or combinations of constants and/or variables with operators.

External Reference

Call to an entry point in another module.

Field

A subdivision of a record that can be referenced by name. For example, the field SEQUENCE_POINTER in a record named SEQUENCE_RECORD is referenced as follows:

SEQUENCE_RECORD.SEQUENCE_POINTER

Hexadecimal Digit

One or more of the following characters.

- Decimal digit 0 through 9
- A through F
- a through f

Integer Constant

One or more digits, the first of which must be a decimal digit. A preceding sign and subsequent radix are optional.

Integer Expression

An expression that, when evaluated, results in an integer.

Load Module

Module reformatted for code sharing and efficient loading. When the user generates an object library, each object module in the module list is reformatted and written as a load module on the object library.

Module

Unit of text accepted as input by the loader, linker, or object library generator. See Object Module and Load Module.

Name

A name is a combination of 1 to 31 characters chosen from the following set.

- Alphabetic characters (A through Z and a through z).
- Digits (0 through 9).
- Special characters (#, @, $, or _).

The first character of a name cannot be a digit.

Object Code

Executable machine instructions.

Object Module

Compiler-generated unit containing object code and instructions for loading the object code. It is accepted as input by the system loader and the object library generator.

Pointer

Address of a value.

Range

A value represented as two values separated by an ellipsis. The element is associated with the values from the first value to the second high value. For example:

value..value

Source Code

Instructions written for input to a compiler.

Statement List

One or more statements separated by delimiters.

String Constant

Sequence of characters delimited by apostrophes ('). An apostrophe can be included in the string by specifying two consecutive apostrophes.

Variable

Represents a data value.

Variable Attribute

A characteristic of a variable. See Access Attribute.

CHARACTER SET B

This appendix lists the ASCII character set (refer to table B-1).

CYBIL P-Code uses the American National Standards Institute (ANSI) standard ASCII character set (ANSI X3.4-1977).

Table B-1. ASCII Character Set (Sheet 1 of 4)

ASCII Code			Graphic or Mnemonic	Name or Meaning
Decimal	Hexadecimal	Octal		
000	00	000	NUL	Null
001	01	001	SOH	Start of heading
002	02	002	STX	Start of text
003	03	003	ETX	End of text
004	04	004	EOT	End of transmission
005	05	005	ENQ	Enquiry
006	06	006	ACK	Acknowledge
007	07	007	BEL	Bell
008	08	010	BS	Backspace
009	09	011	HT	Horizontal tabulation
010	0A	012	LF	Line feed
011	0B	013	VT	Vertical tabulation
012	0C	014	FF	Form feed
013	0D	015	CR	Carriage return
014	0E	016	SO	Shift out
015	0F	017	SI	Shift in
016	10	020	DLE	Data link escape
017	11	021	DC1	Device control 1
018	12	022	DC2	Device control 2
019	13	023	DC3	Device control 3
020	14	024	DC4	Device control 4
021	15	025	NAK	Negative acknowledge
022	16	026	SYN	Synchronous idle
023	17	027	ETB	End of transmission block
024	18	030	CAN	Cancel
025	19	031	EM	End of medium
026	1A	032	SUB	Substitute
027	1B	033	ESC	Escape
028	1C	034	FS	File separator
029	1D	035	GS	Group separator
030	1E	036	RS	Record separator
031	1F	037	US	Unit separator
032	20	040	SP	Space
033	21	041	!	Exclamation point
034	22	042	"	Quotation marks
035	23	043	#	Number sign

Table B-1. ASCII Character Set (Sheet 2 of 4)

ASCII Code			Graphic or Mnemonic	Name or Meaning
Decimal	Hexadecimal	Octal		
036	24	044	$	Dollar sign
037	25	045	%	Percent sign
038	26	046	&	Ampersand
039	27	047	'	Apostrophe
040	28	050	(	Opening parenthesis
041	29	051	)	Closing parenthesis
042	2A	052	*	Asterisk
043	2B	053	+	Plus
044	2C	054	,	Comma
045	2D	055	-	Hyphen
046	2E	056	.	Period
047	2F	057	/	Slant
048	30	060	0	Zero
049	31	061	1	One
050	32	062	2	Two
051	33	063	3	Three
052	34	064	4	Four
053	35	065	5	Five
054	36	066	6	Six
055	37	067	7	Seven
056	38	070	8	Eight
057	39	071	9	Nine
058	3A	072	:	Colon
059	3B	073	;	Semicolon
060	3C	074	<	Less than
061	3D	075	=	Equals
062	3E	076	>	Greater than
063	3F	077	?	Question mark
064	40	100	@	Commercial at
065	41	101	A	Uppercase A
066	42	102	B	Uppercase B
067	43	103	C	Uppercase C
068	44	104	D	Uppercase D
069	45	105	E	Uppercase E
070	46	106	F	Uppercase F
071	47	107	G	Uppercase G
072	48	110	H	Uppercase H
073	49	111	I	Uppercase I
074	4A	112	J	Uppercase J
075	4B	113	K	Uppercase K

Table B-1. ASCII Character Set (Sheet 3 of 4)

ASCII Code			Graphic or Mnemonic	Name or Meaning
Decimal	Hexadecimal	Octal		
076	4C	114	L	Uppercase L
077	4D	115	M	Uppercase M
078	4E	116	N	Uppercase N
079	4F	117	O	Uppercase O
080	50	120	P	Uppercase P
081	51	121	Q	Uppercase Q
082	52	122	R	Uppercase R
083	53	123	S	Uppercase S
084	54	124	T	Uppercase T
085	55	125	U	Uppercase U
086	56	126	V	Uppercase V
087	57	127	W	Uppercase W
088	58	130	X	Uppercase X
089	59	131	Y	Uppercase Y
090	5A	132	Z	Uppercase Z
091	5B	133	[	Opening bracket
092	5C	134	\	Reverse slant
093	5D	135	]	Closing bracket
094	5E	136	^	Circumflex
095	5F	137	_	Underline
096	60	140	`	Grave accent
097	61	141	a	Lowercase a
098	62	142	b	Lowercase b
099	63	143	c	Lowercase c
100	64	144	d	Lowercase d
101	65	145	e	Lowercase e
102	66	146	f	Lowercase f
103	67	147	g	Lowercase g
104	68	150	h	Lowercase h
105	69	151	i	Lowercase i
106	6A	152	j	Lowercase j
107	6B	153	k	Lowercase k
108	6C	154	l	Lowercase l
109	6D	155	m	Lowercase m
110	6E	156	n	Lowercase n
111	6F	157	o	Lowercase o
112	70	160	p	Lowercase p
113	71	161	q	Lowercase q
114	72	162	r	Lowercase r
115	73	163	s	Lowercase s

Table B-1. ASCII Character Set (Sheet 4 of 4)

ASCII Code			Graphic or Mnemonic	Name or Meaning
Decimal	Hexadecimal	Octal		
116	74	164	t	Lowercase t
117	75	165	u	Lowercase u
118	76	166	v	Lowercase v
119	77	167	w	Lowercase w
120	78	170	x	Lowercase x
121	79	171	y	Lowercase y
122	7A	172	z	Lowercase z
123	7B	173	{	Opening brace
124	7C	174	|	Vertical line
125	7D	175	}	Closing brace
126	7E	176	~	Tilde
127	7F	177	DEL	Delete

RESERVED WORDS C

The following are reserved words in CYBIL.

ALIAS	LIST	STRING
ALIGNED	LISTALL	STRLENGTH
ALLOCATE	LISTCTS	SUCC
AND	LISTEXT	THEN
ARRAY	LISTOBJ	TITLE
BEGIN	LOWERBOUND	TO
BOOLEAN	LOWERVALUE	TRUE
BOUND	MOD	TYPE
CASE	MODEND	UNTIL
CASEND	MODULE	UPPERBOUND
CAT	NEWTITLE	UPPERVALUE
CELL	NEXT	VAR
CHAR	NIL	WHILE
CHKALL	NOCOMPILE	WHILEND
CHKNIL	NOT	WRITE
CHKRNG	OF	XDCL
CHKSUB	OFF	XOR
CHKTAG	OLDTITLE	XREF
CHR	ON	#ADDRESS
COMMENT	OR	#CALLER_ID
COMPILE	ORD	#COMPARE_SWAP
CONST	PACKED	#CONVERT_POINTER_TO_PROCEDURE
CYCLE	POP	#FREE_RUNNING_CLOCK
DIV	PRED	#GATE
DO	PROCEDURE	#HASH_SVA
DOWNTO	PROCEND	#INLINE
EJECT	PROGRAM	#KEYPOINT
ELSE	PUSH	#LOC
ELSEIF	READ	#OFFSET
END	REAL	#PREVIOUS_SAVE_AREA
EXIT	RECEND	#PTR
FALSE	RECORD	#PURGE_BUFFER
FOR	REL	#READ_REGISTER
FOREND	REP	#REL
FREE	REPEAT	#RING
FUNCEND	RESET	#SCAN
FUNCTION	RETURN	#SEGMENT
HEAP	RIGHT	#SIZE
IF	SECTION	#TRANSLATE
IFEND	SEQ	#UNCHECKED_CONVERSION
IN	SET	#WRITE_REGISTER
INLINE	SKIP	$CHAR
INTEGER	SPACING	$INTEGER
LEFT	STATIC	$REAL

DATA REPRESENTATION IN MEMORY D

On Control Data 110 computer systems, memory is made up of two bytes per 16 bit word. Table D-1 summarizes how different data types are represented in memory. The alignment column indicates how a variable of the data type is stored in packed and unpacked format. The word "word" means it is stored in the first available word; the word "byte" means it is stored in the first available byte; "bit" means it is stored in the first available bit.

Table D-1. Data Representation in Memory

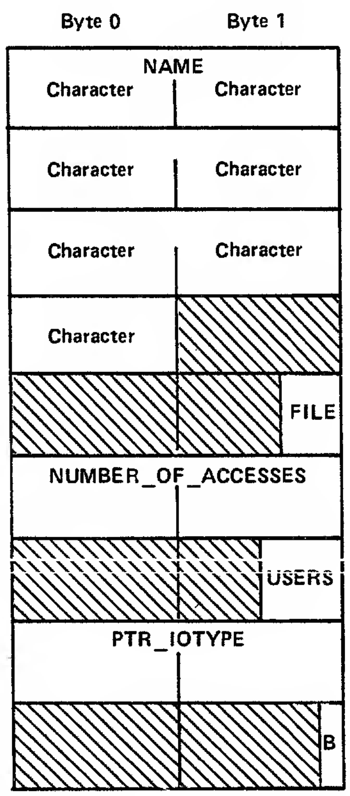
Type	Size	Alignment	
		Unpacked	Packed
Integer	word	word	word
Character	1 byte	word	bit
Boolean	1 bit	word	bit
Ordinal	As needed for components	word	bit
Subrange	As needed for components	word	bit
Real	2 words	word	word
Fixed pointer	word(s)	word	word
Cell	word	word	word
String	1 byte for each character	word	word
Array	word(s)	word	word
Record	word(s)	word	word
Set	word(s)	word	word

The following examples show how a record would look in memory in various formats: first unpacked, then packed, and finally rearranged to use space more efficiently. The memory shown here is in eight-byte words, but because bytes can be addressed individually, it's possible the record could start at any byte (if it is not aligned otherwise).

The unpacked record is:

```
TYPE
  table = RECORD
    name : string(7),
    file : (bi, di, lg, pr),
    number_of_accesses : integer,
    users : 0..100,
    ptr_iotype : ^iotype,
    b : boolean,
  RECEND;
```

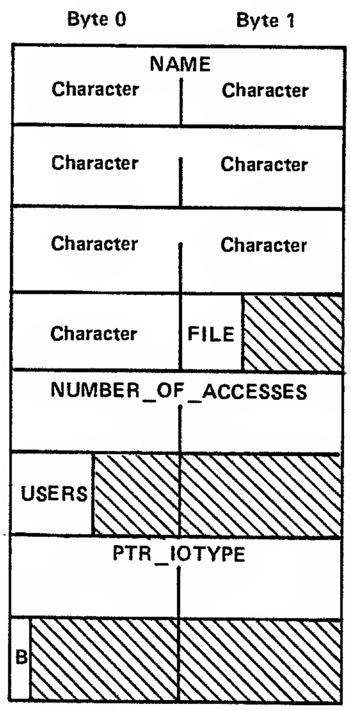
This record would appear in memory as follows (slashes indicate unused memory):



The packed record is:

```
TYPE
  table = PACKED RECORD
    name : string(7),
    file : (bi, di, lg, pr),
    number_of_accesses : integer,
    users : 0..100,
    ptr_iotype : ^iotype,
    b : boolean,
  RECEND;
```

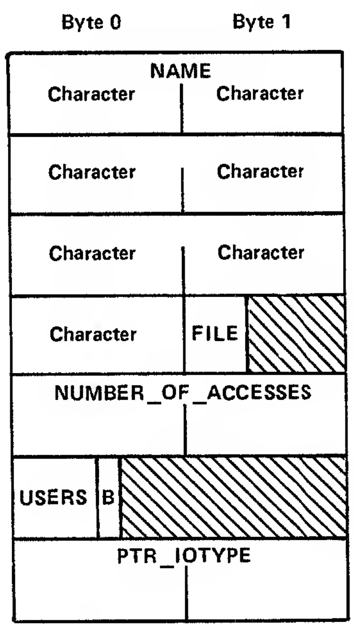
This record would appear in memory as follows (slashes indicate unused memory):



The record, as follows, is now rearranged slightly to make more efficient use of the space.

```
TYPE
  table = PACKED RECORD
    name : string(7),
    file : (bi, di, lg, pr),
    number_of_accesses : integer,
    users : 0..100,
    b : boolean,
    ptr_iotype : ^iotype,
  RECEND;
```

This record would appear in memory as follows (slashes indicate unused memory):



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